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A HIGH HEAD WATER POWER ELECTRIC PLANT ON THE ANIMAS RIVER, COLO.

By Geo. M. Peek,* M. Am. Soc. M. E.

There has recently been completed in San Juan County, Southern Colorado, a water-power plant employing a static head of nearly 1,000 ft. and generating electric current at 50,000 volts pressure for long distance transmission to the important mining camps of Durango and Silverton, located about 25 miles away. The work has been done by the Animas Canal, Reservoir, Water Power Investment Co., which has already contracts for the supply of about 4,000 HP. from its plant.

Water is taken from Cascade Creek, which has a flow of 3,720 cu. ft. per minute and is carried through a 6 × 8 ft. wooden flume 3½ miles long into a natural water course emptying into an artificial reservoir with an area of 960 acres. The drainage basin supplying this reservoir has a runoff of 1,500 cu. ft. per minute, making a total supply of 5,220 cu. ft. per minute. The reservoir was made by building a stone and timber dam 750 ft. long, 55 ft. high, with its foundation carried 33 ft. deep to solid rock.

It is proposed eventually to replace this dam by one of concrete 100 ft. high and about 1,400 ft. long. This will increase the reservoir to 1,161 acres. It is also the intention at the same time to bring water from Lime Creek into the reservoir. This can be done by building another flume four miles long, and the total water supply will be thus increased to 10,440 cu. ft. per minute.

EARTH AND CRIB DAM AT 960-ACRE STORAGE RESERVOIR OF THE ANIMAS COMPANY, COLORADO.

At some future time as the demand for power increases it is proposed to take water from the Animas River. In order to do this it will be necessary to drive a tunnel 8 miles long, but when this is done the water supply will be sufficient to develop 38,000 HP.

From the large reservoir the water is carried in a wooden flume 8,800 ft. long and 3 ft. 2 ins. by 4 ft. 8 ins. in the clear to a small intake reservoir covering about five acres.

The dam at the intake reservoir is made of earth with a concrete core 3 ft. thick and a concrete retaining wall at the toe. It is 30 ft. high and about 100 ft. long. This dam is to be raised 10 ft., which will give an effective head of 970 ft. at the power house.

The pipe to the power house leaves the intake reservoir at a point 25 ft. below the surface of the water, thereby avoiding any possibility of ice entering or blocking the pipe. Where the pipe emerges from the dam there is a 44-in. gate-valve and just beyond the valve is a 10-in. stand-pipe to allow air to enter the pipe, when the valve is closed, and prevent any danger of the pipe collapsing.

The opening of the pipe inside the dam is 60 ins. in diameter, which is at once reduced to 44 ins.; and this continues until a head of 125 ft. is reached, when the diameter is reduced to 40 ins., and still further down to 36 ins. and 34 ins. The thickness of the pipe varies from ¼-in. at the dam to 11-16-in. at the power-house, and the riveting is varied to correspond to the pressure to which the pipe is subjected. The total length of the pipe line is 2,844 ft.

The pipe was made up in 30-ft. sections fitted with welded steel angle flanges, which are bolted together with combination lead and copper gaskets between them. The heaviest sections of pipe weigh six tons each. The steepest grade on the line is 84%. At the power house and lower bends the pipe is anchored in large blocks of concrete, each block being made of sufficient size to carry the weight of the pipe above it. The sections of pipe at the lower end were tested to 650 lbs. per sq. in. before leaving the shops of the Pelton Water Wheel Co., which furnished the piping and water wheels. The pipe was hauled up the incline with a mine hoist and cable. In addition to the large concrete blocks at the foot of the incline for taking the downward thrust, the pipe is securely anchored in position by other concrete along the line.

At the lower end of the pipe line there is a cast steel Y tapering down to two 20-in. branches connecting to 20-in. gate valves with by-passes and roller bearings for connection to the needle nozzles of the wheels.

The wheels are 8-ft. Pelton wheels overhung on the generator shafts with a normal capacity of 3,000 HP. each of 300 R. P. M., but capable of being run up to 4,000 HP. The wheel centers, as also the buckets, are made of cast steel. Each bucket is bolted to the center with one 2¼-in. and one 1¾-in. bolt, giving ample strength to permit the wheels being locked and the full stream turned on. The shafts are 14 ins. in diameter at the bearings and 16 ins. in diameter at the fields. The shafts have a 5-in. hole through them through which water is run to assist in keeping the bearings cool.

The bearings are 42 ins. long and are made with only the lower half babbitted. The upper part has a cover with guides for the oil rings, of which there are six to each bearing. In the lower part of the bearings are coils of pipe for water cooling.

The nozzles are by-pass needle nozzles. The power given to the wheels varies as the ordinates of a curve for a uniform motion of the needle and in order that the power delivered to the wheels may vary uniformly for a uniform rotation of the governor shafts a system of toggle levers is arranged so that the needles will move as the ordinates of a curve when the governor shafts are rotated uniformly. In order to avoid water hammer on the pipe when the load is thrown off the generators, there is a by-pass arranged to be opened by the governor when it closes the nozzle on the wheel. The wheel nozzle needle and the by-pass nozzle needle are connected together by means of a right and left-hand screw with a handwheel, so that the station attendant, by means of a predetermined load curve, can set the screw at certain hours of the day, so that the amount of water passing will be sufficient for the average power required and reduce the loss to a minimum. The wheels are controlled by oil pressure governors with two pumps so arranged that one can furnish power for either or both in case of an accident to one of them.

The generators are 2,250-KW. revolving field 3-phase 60-cycle alternators with the exciter armatures mounted on the shafts. The generator voltage is 4,000, which is raised by step-up transformers to a line voltage of 50,000. There are six water-cooled oil transformers of 750 KW. capacity each. Each transformer is located in an iron and cement vault completely closed, so that

*143 Liberty St., New York City.

in case of damage by lighting the oil cannot burn and damage the building or apparatus, as no air can get to it. The generators are supplied with voltage regulators which obviate any difficulty in keeping the voltage constant with the exciter armatures on the generator shafts. The generator mains pass up to the oil switches and circuit breakers through brick chambers whose walls form barriers. Each transmission line passes

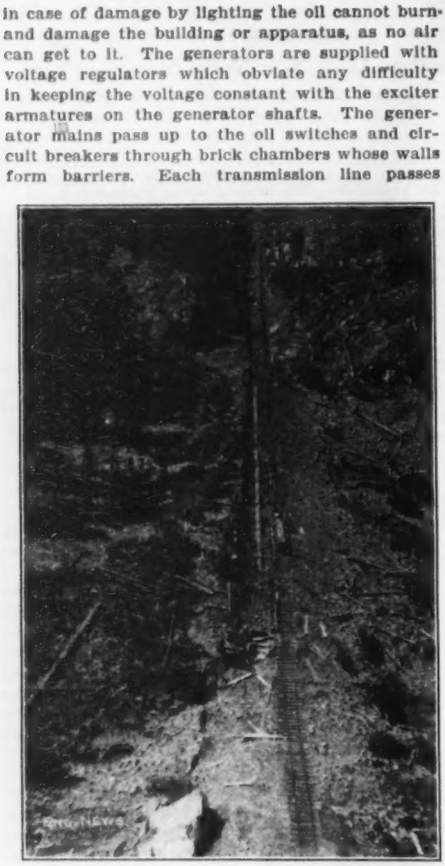

Fig. 1. Pipe Line Adjacent to Animas Power House, Maximum Grade, 84%.

through a separate brick chamber to the exterior of the building.

The switchboard is located on a gallery over the transformer vaults where the attendant has in full view all of the machinery in the building.

The transmission line is made of three cables each, composed of six aluminum No. 8. B. & S. wires with a hemp core. These cables have a conductivity equal to that of No. 2 B. & S. copper wire. They are arranged on poles to form a triangle of 6-ft. sides. The poles are 36 ft. long, set 6 ft. in the ground and spaced 250 ft. apart. The longest span in the line is 1,100 ft. where the wires are suspended between wooden towers across an arm of the main reservoir.

There is a substation in Silverton with transformers which reduce the pressure to 17,000 volts. As a matter of safety against interruption there are two independent circuits running to Silverton.

Another substation is to be built in Durango. At present two generating units are installed in the power house and two more are to be placed as soon as possible.

A great deal of credit is due Mr. H. T. Henderson, of Durango, the Chief Engineer and General Superintendent of the Animas Co., as it was his push and energy that caused the power plant to be built.

THE STRUCTURAL DESIGN OF TOWERS FOR ELECTRIC POWER-TRANSMISSION LINES.

By Joseph Mayer,* M. Am. Soc. C. E.

The most extensive experience with structures approximately answering the purpose of electric transmission line towers has been with timber telegraph poles. There are several important differences between telegraph or telephone and power transmission lines. On the former are small wires, frequently numerous, which carry harmless currents. The overturning of one line by an exceptionally severe storm accompanied by sleet on the wires, causes comparatively little inconvenience. This combination is rare and local, and the wind pressures along the narrow track of the storm center are several times as large as those commonly occurring. The percentage of lines of the now usual strength yearly destroyed is small. To build all the lines strong enough to resist the most exceptional wind pressures would cost much more than to follow the present practice and to replace the few lines destroyed. On power transmission lines the overturning of a line is a more serious matter, causing great inconvenience, and the dangerous currents may cause loss of life. Such lines should therefore be built strong enough to resist not only the commonly occurring, but also the exceptionally violent local storms. The degree of safety aimed at in buildings and bridges, and the wind pressures assumed in their design, are therefore better guides in the design of such lines than the precedents furnished by telegraph pole lines.

WIND PRESSURE.—Bridges were first generally designed without scientific determination of the wind strains. Terrible disasters were an occasional consequence. One of these, the fall of the Tay bridge in Scotland, with a crowded passenger train, drowning all on board, led to the English standard for wind pressures, which is 56 lbs. per square foot of plane exposed surfaces and one-half as much for cylindrical surfaces (counting diameter into length as the exposed area). In this country 50 lbs. per square foot of exposed surface is a frequent standard. The most eminent engineers are, however, now of the opinion that such pressures occur only over small surfaces, and that 30 lbs. per square foot of exposed surface is a liberal allowance for areas extending over considerable distances. The larger pressures assumed in the design of short-span bridges are chosen mainly for resisting the tendency toward lateral vibration under rapidly moving trains. The great difference between the pressure on large and small areas arises from the fact that the wind pressure acts in gusts or is oscillating, and the oscillations are not synchronous over any considerable extent of space. The wind pressure over a large area, or one extending at least in one direction over a considerable distance, approaches the average of the pressure during the oscillations, while a small pressure gage gives the maximum. The New York Building Code and many other building laws prescribe for high buildings 30 lbs. per square foot of exposed surface.

The observed wind pressures greatly decrease as one approaches the surface of the ground. This is an additional reason why an assumed wind pressure of more than 30 lbs. per sq. ft. is unreasonable for a transmission line the towers of which are rarely more than 60 ft. high. Pressures on cylindrical surfaces are by experiment shown to be only 0.5 to 0.6 those on plane surfaces. A pressure of 18 lbs. per square foot of exposed surface of wires, counting the product of diameter into length as the area, is, therefore, a liberal assumption.

ICE LOAD.—Another force endangering the safety of a line is the weight of the ice gathering on the wires. This force is generally more important for telegraph than for power-transmission lines. Telegraph wires of ¼-in. diameter have a cross-section area of 0.0075 sq. ins. Strands of 350,000 c. m. used for the transmission of large amounts of power are of 0.67-in. dia. and have a cross-section of 0.275 square inches. A coat of ice ½-in. thick increases the diameter and the area exposed to wind in the former case nine times, in the latter less than three times. The weight carried by copper wires is increased nine times in the former and 1.7 times in the latter case. The power transmission lines carry, at least during part of the day, a large current producing considerable heat, which hinders the accumulation of a large amount of ice.

A very important fact in judging the amount of wind pressure on the wires is also the absence of tornadoes during very cold weather. In a recent article in the Geographical Magazine for June, 1905, by Professor Willis L. Moore, Chief of the Weather Bureau, the conditions for the occurrence of a tornado are given; one of them is a temperature of about 70° F. at 8 o'clock in the morning. Tornadoes are the only storms which produce near the surface of ground wind pressures at all approximating those assumed. While it may, therefore, be reasonable to assume in our climate a coat of ice ½ in. thick, increasing the diameter 1 in., it is not reasonable to assume this coat at the same time with the maximum wind pressure. The wind pressure on the tower itself is also much smaller in severest winter weather than during the tornadoes of spring and summer. The latter seasons are therefore probably the most dangerous for the towers of power transmission lines with three or six large strands, while for the numerous small wires of telegraph lines and their poles the ice-covered wires exposed to winter storms are most likely to cause their destruction.

In the design of a line the first thing is to select the least clearance between the wires and the surface of ground. This is determined by considerations of safety, and is partly dependent on the voltage of the current. The distance between the three wires of a circuit also depends on the voltage and on the altitude of the region above sea level. The rarified air of high altitudes is a poorer insulator than the denser air near sea level. The wires must be farther apart in the former than in the latter case, to secure the same amount of leakage between the wires; 60,000 volts is now about the upper limit of voltage and 7 ft. distance between the wires has been chosen for lines near Niagara Falls for this voltage.

The best distance between towers can only be determined by making designs for different spans and comparing their cost. The great cost of high tension insulators and the high cost of timber, together with its perishable nature, have made short span timber pole lines uneconomical for

Fig. 2. The Pipe Line Under Construction.

high tension power transmissions. Steel towers have so far taken their place, and they will be probably followed by towers of reinforced concrete. Spans between 300 and 800 ft. are economical for different designs and sizes of wire.

After the span is assumed the maximum deflection of the wires must be determined. To calculate the latter with a given size and strength of wire or strand, the amount of ice, the wind pressure with and without ice, and the maximum tension in the wire must be chosen.

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ASSUMED DATA.—A coat of ice 1 in. thick, making the diameter 2 ins. plus diameter of wire, has been assumed by some engineers, with a unit strain of 40,000 lbs. per sq. in. on hard-drawn copper wires. The amount of ice and the unit strain are about equally excessive, and the result obtained with some sizes of wire is not unreasonable. A ½-in. coat of ice will by most be considered a sufficient allowance in all places except near waterfalls. It is claimed by some that the heat produced by the current will prevent the formation of ice. The elastic limit of strands made of small wires about No. 10 B. & S. gage is at least 35,000 lbs. per sq. in. A unit strain equal to two-thirds the elastic limit will give about the degree of safety adopted for bridges and buildings. The proper wind pressure for the bare wire was given as 18 lbs. per square foot; that for the ice-covered wire will be differently estimated from the few known data. With the moderate unit strain here assumed it will be safe to take the total wind pressure on the ice-covered wire the same as on the bare wire for a strand of 350,000 c. m. and 0.67-in. dia. The weight of such a strand is 1.05, and with ¼-in. thick ice 1.8 lbs., per foot. The assumed wind pressure acting normal to the weight is 1 lb. per ft. A considerable difference in the assumed wind pressure will not much affect the resultant maximum deflection with a given strain or the maximum strain corresponding to a given maximum deflection. For calculating the latter the greatest variation in the temperature of the wire is required. This is about 150° F. in the eastern and central United States, but is generally much less in tropical and subtropical countries. The modulus of elasticity of hard-drawn copper strands may be taken as 16,000,000 lbs. per sq. in. The coefficient of expansion per degree Fahrenheit is 1 ÷ 104,400. A sufficiently approximate formula for the length of the wire between two insulators is $S = L + \frac{8\,D^2}{3\,L}$, where S is the length, L the span, and D the deflection.

CALCULATION OF DEFLECTION AND STRESS.—I shall take as an example a 660-ft. span and a strand of 350,000 c. m., or 0.275 sq. ins. With the above given weight and wind pressure the force acting on the strand is $\sqrt{1.8^2 + 1^2} = 2.06$ lbs. per lin. ft. The permissible strain in the strand, if taken at two-thirds the elastic limit, is 6,417 lbs. Its deflection at minimum temperature with the assumed wind pressure and ice ½-in. thick, is given by the formula

$$D = \frac{660^2 \times 2.06}{6{,}417 \times 8} = 17.48 \text{ ft.}$$

The deflection of this strand at maximum temperature under the influence of its own weight must be found to determine the height of the wire at insulators. The shortest way, after some experience, is to guess at the deflection, calculate the strain in the wire, its length corresponding to the strain and temperature, and also the length corresponding to the deflection. The two lengths should agree; if they do not, another guess must be made and the calculation repeated. The length of wire with 17.48 ft. deflection is

$$S = 660 + \frac{8}{3} \cdot \frac{17.48^2}{660} = 661{,}234 \text{ ft.}$$

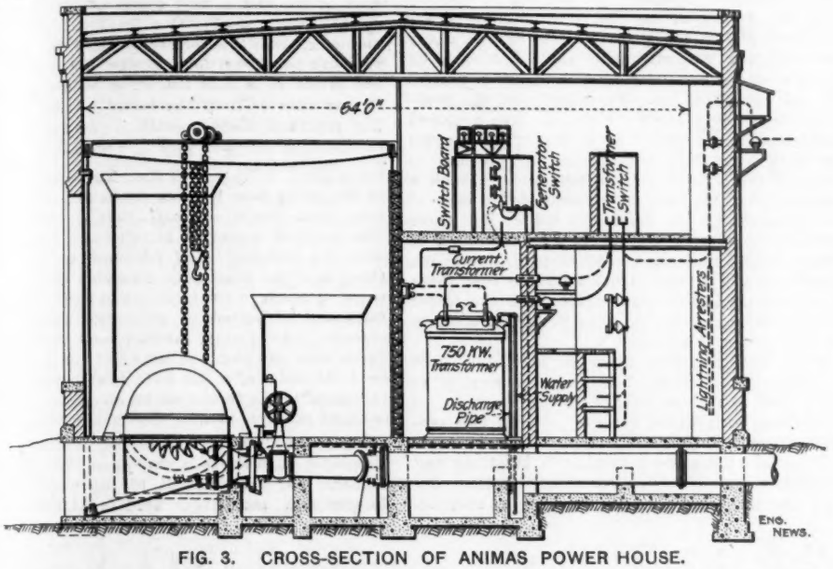

FIG. 3. CROSS-SECTION OF ANIMAS POWER HOUSE.

This deflection obtains with a strain of 6,417 lbs. in the wire at minimum temperature. If we now guess the maximum deflection to be 20 ft. the strain is

$$t = \frac{660^2 \times 1.05}{8 \times 20} = 2{,}858 \text{ lbs.}$$

The reduction in strain is 6,417 — 2,858 = 3,559 lbs. The shortening of the wire due to this reduction is (3,559 × 661.2) ÷ (0.275 × 16,000,000) = 0.535 ft. The lengthening of the wire due to change of temperature is (661.234 × 150) ÷ 104,400 = 0.950 ft. The length of the wire at maximum deflection calculated from strain and temperature is 661.234 + 0.950 — 0.535 = 661.649 ft. The length of the wire calculated from the deflection is $S = 660 + \frac{8}{3} \cdot \frac{400}{660} = 661.616$ ft. The length calculated from deflection is 0.033 ft. too short. The actual deflection is therefore a trifle larger than guessed at.

Mr. F. O. Blackwell has found for hard-drawn copper cable a modulus of elasticity of 12,000,000 lbs. instead of the 16,000,000 lbs. here assumed. This modulus depends on the length of twist, and varies with different cables. If 12,000,000 lbs. is taken, the maximum deflection becomes 19 ft. 2 ins. for our example.

The maximum deflection and the clearance give together the height of the lower insulators.

LONGITUDINAL FORCES.—The forces acting on the towers in a direction normal to the line have been discussed in the foregoing. They are, at least with large strands, probably greatest during tornadoes when there is no ice on the wires. The forces in the direction of the line depend on the design adopted. As long as all the wires are intact, practically the only force acting in the direction of the line is the wind pressure on the towers. If a wire breaks there is a one-sided pull at the two nearest insulators. With a No. 8 B. & S. gage wire this pull is at most a few hundred pounds, and the insulator, its pin, the cross-arm and the tower can easily be made strong enough to resist it without sliding of the wire as insulators. With a strand of 350,000 c. m. of hard-drawn copper, the tension at minimum temperature with ½-in. ice is, in accordance with the deflection here recommended, 6,417 lbs. This would require, with wires firmly attached to the insulators, very strong and expensive insulators, pins, cross-arms and towers. To avoid the consequent excessive cost, the strands must in this case be so connected to the insulators that they can slide without too much friction. If this friction is made very small the breaking of a strand will make it slide along a large number of insulators on each side of the break, and it will come down to the ground in several spans.

There may be distinguished three different methods of meeting this problem. The wires may be firmly attached to all insulators so as to prevent their sliding. This is practicable with small wires, especially where they are numerous. Where there are only three large wires or strands, two of them on a long cross-arm, and all supported on pyramidal towers, the breaking of one wire at one end of cross-arm will twist the adjacent towers. This twisting will so change the length of the adjacent spans of the wire at other end of cross-arm as to produce a torsion partly counterbalancing the first. The towers nearest the break are exposed to a one-sided pull at both ends of cross-arm and to a torsion. To make these forces moderate and keep the cost of the towers within financially practicable limits, the wires are loosely attached to the insulators, so that they can slide; in this case, the forces arising from the breaking of a wire are distributed over several insulators, cross-arms and towers.

To keep the distance along which this sliding of the wire at insulators takes place within moderate limits two methods are available. The

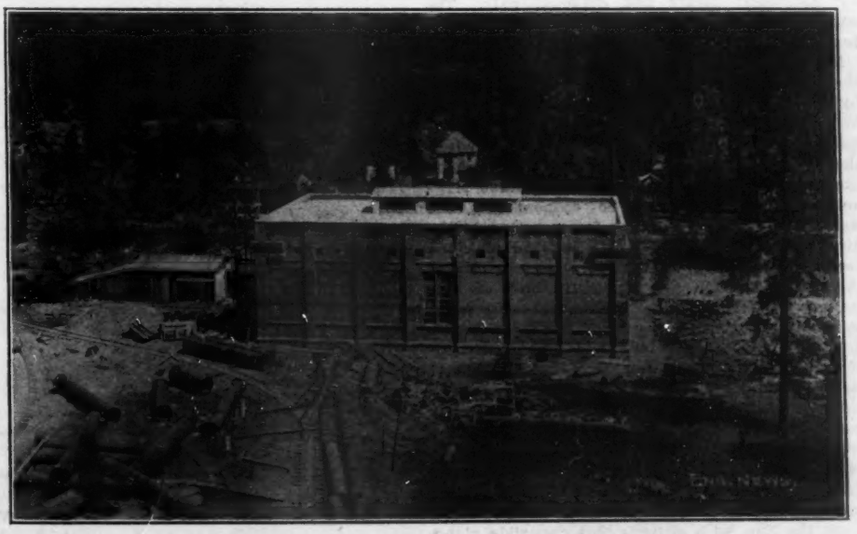

FIG. 4. VIEW OF BACK OF POWER HOUSE FROM PIPE LINE.

wires may be so attached to the insulators that there is considerable friction, and the towers designed to resist the forces arising therefrom; or stronger towers may be placed at intervals with double insulators and extra strong insulator pins and cross-arms, with the wires firmly attached to the insulators. In this latter case the ordinary towers can be safely built without much torsional strength. The wires should then be so attached to the insulators of ordinary towers as to permit easy sliding, or the cross-arm should be so connected to the tower that it can swivel around it, or the tower should be flexible to permit its twisting without over strain, or all three may be to some extent combined.

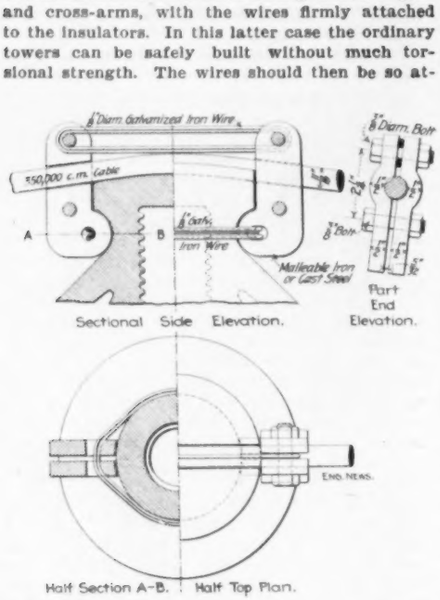

Fig. 1. Proposed Design of Sleeve or Friction Clamp for Fastening Power Transmission Line Wires to Insulators.

This solution of the problem has been adopted on some lines under construction near Niagara Falls. The extra strong towers at intervals are provided with guys attached at both ends of the cross-arms and going in both directions of the line, which relieve the towers of torsional strains and of forces acting in the direction of the line. These towers consist of three 2½-in. gas pipes forming a triangular pyramid; they are braced by horizontal struts and diagonal rods. The connections are by means of malleable iron castings.

If all the towers are made of the same strength the greater torsional forces may be provided for by building towers consisting of two triangular bents having their planes parallel to the transmission line as far apart as the two side wires, the third wire being in the center between them, the two bents braced together by struts and diagonals. Such towers can be economically designed to resist much larger forces acting in the direction of the line than can well be provided for in pyramidal powers. Towers for two lines of three strands each are frequently built in this manner with the distance between the bents equal to that from center to center of line.

The attempt to provide for a line consisting of three large strands, towers of great torsional strength, and able to resist large forces in the direction of the line which arise from the breaking of one or more firmly attached strands, greatly increases the cost of the towers as soon as these forces are assumed to be larger than those acting normal to the line. The only drawback of towers of equal strength normal to and along the line, with strands that can slide along the insulators with sufficient ease to make the towers safe when one or more strands break, is the sliding of the strands over a considerable distance from each side of the break. With large strands, with the factor of safety here assumed, and with careful inspection and testing of the strands for strength, the breaking of a strand will be an extremely rare occurrence. It is therefore not economical to build towers that are safe with firmly attached strands for the purpose of avoiding the inconvenience arising from this sliding of the strand in case of a break. By using sleeves or clamps made in halves surrounding the strands at the insulators they can be firmly attached to the latter without producing large friction against sliding. A design by the author for such a friction fastening is represented in Fig. 1 herewith. Friction opposing the sliding of a strand is larger at the start than after the motion has begun.

With the towers here chosen for an example, for three strands of 350,000 c. m. and 660-ft. spans, a pull of 1,000 lbs. at any one of the strands or one of 2,000 lbs. at the three strands can be easily provided for without much additional cost, by towers having equal strength in direction normal to and along the line. The solution of the problem of the forces along the strands here proposed is to design the towers so that they have equal strength normal to and along the line, and to connect the strands to the insulators in such a manner that the towers are safe in the case of their breaking. In pyramidal towers for three strands the torsion arising from the breaking of a side strand produces considerable strains in the diagonals and lateral struts near the top; these can be made larger than required for the forces acting normal to the line with but slight increase in the cost of the towers.

There are generally built at least two lines of three wires each. The cheapest way is to carry the two lines on one row of towers. A safer way with 60,000 volts is to build two separate rows of towers each for one line.

To secure the same safety as in buildings and bridges, the unit strains customary in their design (for dead and wind loads) must be adopted.

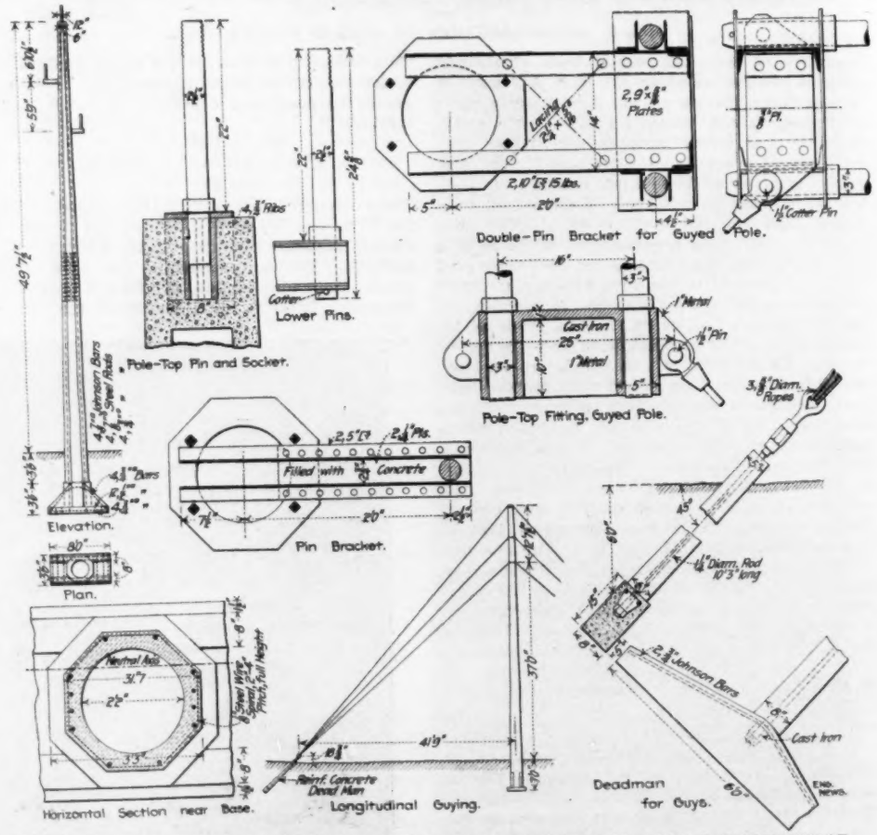

FIG. 2. REINFORCED-CONCRETE POLE WITH SPREAD BASE, FOR SINGLE THREE-PHASE POWER TRANSMISSION LINE.

For spans of 400 ft.; 30 ft. minimum clearance; 9 ft. maximum deflection; every 6th pole guyed by six guy-wires as shown; unit stress in steel, 20,000 lbs. per sq. in.; unit stress in hooped concrete, 640 lbs. per sq. in. Material for one pole: All metal, 1,570 lbs., 1:2:4 concrete 4.6 cu. yds.

ing the unsupported length of the struts and r their radius of gyration).

There exists no uniformity of practice in regard to the subjects discussed in the foregoing. In the calculation of the proper deflection some advocate for copper strands a wind pressure of 10.5 lbs. per sq. ft. of wire without ice (they claim that no ice is formed on power transmission wires) and a unit strain of 40,000 lbs. per. sq. in.; others advocate a wind pressure of 25 lbs. per sq. ft. of ice-covered wire with ½-in. thick coat of ice and a unit strain of 20,000 lbs. per sq. in. With a 350,000 c. m. strand of 0.67-in. diameter, and the former assumption the wind pressure per lineal foot of wire is 0.59 lbs., with the latter it is 3.38 lbs. The weight is in the former case 1.05; in the latter 1.8 lbs. per foot. The resultant force normal to the line is in the former case $\sqrt{0.59^2 + 1.05^2} = 1.20$ lbs.; in the latter $\sqrt{1.8^2 + 3.38^2} = 3.83$ lbs. The assumed force in the latter case is three times and the permissible unit strain one-half that in the former. The required deflection at minimum temperature with the assumed wind pressure and ice is six times and the maximum deflection is more than twice as much in the latter as in the former case. Both are advocated by prominent electrical engineers. The former assumptions more closely agree with the common practice; the latter have been the basis of a line built near Niagara Falls. In regard to the forces acting along the line there is equal or even greater divergence of opinion.

The calculation of the proper deflection for aluminum conductors is similar to that given for copper. The elastic limit of the stranded conductors now exclusively used is 14,000 lbs. per sq. in., the ultimate strength 26,000 lbs., and the modulus of elasticity 9,000,000 lbs.; the coefficient of linear expansion is 0.0000128 per degree Fahrenheit. The specific gravity is 2.68 and the conductivity of conductors 99% pure is 62% that of pure copper. If we take a line made up of three strands each of 500,000 c. m., which is

For medium steel of 60,000 to 70,000 lbs. ultimate strength and 36,000 lbs. elastic limit, a unit strain of 20,000 lbs. per sq. in. net section can safely be taken in tension and one of $20{,}000 - 80 \frac{l}{r}$ per sq. in. of gross section in compression (l be-

about of the same conductivity as the copper line of our previous example, we have a ⅞-in. strand of 0.44 sq. ins. The calculation, assuming the same thickness of ice, the same wind pressure per square foot, and the same factor of safety, gives for a 660-ft. span a deflection of 27 ft. 8 ins. as against 20 ft. with copper conductors of the same capacity. Mr. F. O. Blackwell found for hard drawn aluminum cables a modulus of elasticity of 7,500,000 lbs. If this is used instead of 9,000,000 lbs. taken above the maximum deflection becomes 27 ft.

THE FOUNDATION.—There are two different types of foundations for such towers.

1. If the three or four posts are not more than 5 ft. apart at the base the foundation is frequently a cylindrical or prismatic block of concrete. The posts may be embedded in the concrete or anchored to it by means of bolts. When the tower is exposed to lateral pressures the upper part of this block presses horizontally against the earth on the leeward side, the lower part on the windward side. The upward pressure on the base balancing the weights is on the leeward side. There is also a shear between the vertical sides of the concrete block and the earth; this acts upwards on the leeward and downwards on the windward side. These three groups of forces must produce a moment equal to the overturning moment of the wind or other lateral force.

2. When the three or four posts are far apart a separate mass of concrete is provided for each post. These masses are exposed to downward and upward forces at small angles against the vertical. The weight of the blocks and the friction between them and the earth are the principal opposing forces. To reduce the amount of concrete required such foundations are sometimes built with a platform made of reinforced concrete at their base. The weight of the earth over this platform (contained in a pyramid sloping out from the edges at an angle of 45° in all directions) is counted as resisting the upward pull of the anchor bolts and a factor of safety of 2 is adequate.

The cost of the foundations is a quite important part of the cost of the towers, their accurate calculation is therefore desirable. The second type offers no special difficulty. For the first type telegraph poles furnish the most reliable precedent. It may be safely assumed that during the long years they have been in use the depth to which they must be set to make the resistance of the ground equal to their strength has been correctly ascertained.

The safe strength of a telegraph pole, or the moment it can safely resist, may be taken with a factor of 5 as

$$m = \frac{\pi d^3}{32} 1{,}500,$$

where d is the diameter of the pole at place of maximum moment in inches, and the moment m is in inch-pounds.

The usual practice in setting poles is about as follows:

Poles 12 ins. diam. are set 5 ft. 0 ins. deep.
Poles 12½ins. diam. are set 5 ft. 6 ins. deep.
Poles 13 ins. diam. are set 6 ft. 0 ins. deep.
Poles 14 ins. diam. are set 6 ft. 6 ins. deep.
Poles 16 ins. diam. are set 7 ft. 0 ins. deep.

NOTE.—The diameters are 6 ft. from butt.

The largest bending moment to which the poles are exposed occurs at about ¼ the depth of the buried portion where the diameter is ½-in. more. From the above formula for the moment in inch-pounds which a timber pole can safely resist we obtain the moment in foot-pounds: $M = 12.27\ d^3$. We obtain for different diameters at ¼ the depth of buried portion the following safe moments in foot-pounds, and the usual depths h of setting.

d ins.	M ft.-lbs.	h ft. ins.
12.25	22,550	5 0
12.75	25,430	5 6
13.25	28,540	6 0
14.25	36,030	6 6
16.25	52,650	7 0

Concrete foundations of towers, as here contemplated, are of larger dimensions than the buried part of the telegraph poles, and they must

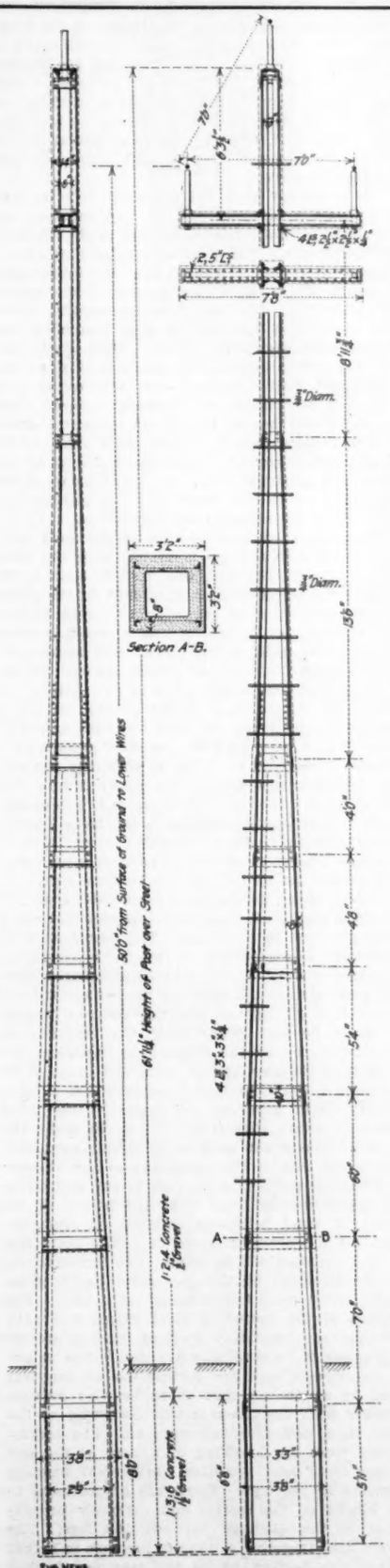

Fig. 3. Four-Post Reinforced-Concrete Tower with Prismatic Base, for Single Three-Phase Power Transmission Line.

For spans of 660 ft.; 30 ft. minimum clearance; 20 ft. maximum deflection. Assumed wind pressure, 660 lbs. at each insulator, and 40 lbs. per vertical foot of tower; unequal pull, 1,000 lbs. at one wire or 667 lbs. at each wire; assumed ice coating ½-in. Material for one tower: All metal, 2,040 lbs. 1:2:4: and 1:3:6 concrete, 5.8 cu. yds.

safely resist much greater moments. We must, therefore, ascertain how a change in the dimensions will affect the moments which can be resisted. The safe resistance of the earth against the overturning of the foundation may be subdivided into three parts.

I.—The moment of the horizontal lateral forces acting on the vertical sides of the foundation. These forces per square foot of surface increase about in proportion to the depth. Their total amount, therefore, increases in proportion to the square of the depth of the foundation; it also increases in proportion to its diameter. The leverage of the two opposite resultants of the horizontal forces increases as the depth of the foundation. The moment of these horizontal forces opposing the overturning of the foundation is therefore proportional to its diameter and to the cube of the depth.

II.—The vertical shears between the foundation and the earth or the frictions are proportional to the horizontal pressures; these latter are proportional to the diameter and the square of the depth; the same applies therefore to the former. The leverage with which these frictions act is proportional to the diameter. The moment of these frictions which is the product of their amount into the leverage is therefore proportional to the square of the depth and the square of the diameter.

III.—The upward pressure from the base is equal to the weight carried. When the foundation is exposed to overturning forces this upward pressure acts on the leeward side, its leverage is approximately proportional to the diameter. The weight of the foundation is an important part of the whole weight; if it were the whole weight this last moment would be proportional to the depth and the cube of the diameter.

Thus, if the diameter and depth of base are increased in the same proportion the moment which can be safely resisted increases approximately with the fourth power of the lineal dimension of the foundation. The only item which does not comply exactly with this ratio is the resisting moment of the pressure on the base due to weight of pole and wires. This item is a small one with telegraph poles and will not materially vitiate the inference here drawn.

For calculating foundations with different ratio of depth to diameter and for square prismatic foundations a formula is required giving their safe strength as a function of diameter or side of the square cross section and the depth. It is a safe assumption that a square foundation will be stronger than a round one having as cross-section the circle inscribed in the square. From the above-cited figures for experience with telegraph poles we may reliably conclude that in ordinarily firm soil a round or square foundation 13¼ ins. in diameter and 6 ft. deep will safely withstand a bending moment of 28,500 ft.-lbs. The safe resistance of soil of various kinds against forces acting vertically is approximately known. From this the safe resisting moment of the forces acting on the base may be estimated and subtracted from the 28,500 ft.-lbs., and from the remaining moment the safe lateral pressure per square foot of the earth on the foundation can be obtained. This safe lateral pressure or safe passive earth pressure can also be obtained from published results of experiments. This latter method has been tried by the writer but the results obtained differ so widely from the actual experience with telegraph poles that they are quite misleading.

Concrete foundations are mostly square or rectangular prisms; their size can be calculated if the safe vertical pressure on the base, the safe horizontal pressure on the sides, and the safe coefficient of friction between the sides and the earth are known. If the safe coefficient of friction is assumed to be 1-3, if the safe pressure on the bottom per square foot is assumed to be 1,160 lbs. multiplied with the depth below surface in feet, and if the safe horizontal lateral pressure per square foot is assumed to be 1,160 lbs. multiplied by the depth below surface in feet then calculation gives for a concrete foundation 13¼ ins. square and 6 ft. deep, a safe strength to resist an overturning moment of 28,500 ft.-lbs.

Unless the present practice of setting a pole of this diameter 6 ft. deep is in error such a foundation, even if round instead of square, will resist a moment of 28,500 ft.-lbs. with a factor of safety of 5. The lateral pressure on the ground and the friction due to it are the only important items in the stability of telegraph poles. The constant of 1,160 lbs. for the safe lateral pressure of the earth at a depth of 1 ft. below ground must therefore be approximately correct. To be, however, quite on the safe side and to allow for greater variations in the nature of the ground than is usual with telegraph poles, it would be better to take, if but one kind of foundation is used, 800 lbs. multiplied by the depth in feet as the safe lateral pressure per square foot. In a power transmission line with three or six large strands the greatest lateral forces occur during tornadoes and in warm weather; on a telegraph line the greatest lateral forces occur with sleet-covered wires when the ground is frozen. From this it follows that in wet ground the foundations of a telegraph line are strengthened by frost when the largest forces occur, while this is not the case with a power transmission line. Greater caution in wet ground is therefore required with the latter. In setting telegraph poles the nature of the ground is taken into account in selecting the depth of setting which is varied somewhat according to it. In designing concrete foundations for steel towers it is advisable to make at least two designs, one for compact gravel with 1,000 lbs. unit pressure at unit depth, and another with 600 lbs. where there is a considerable depth of soft soil. The latter foundation will be from 1 ft. to 1½ ft. deeper than the former.

On a subject which is so variable as the resistance of the ground against lateral forces opinions of different engineers will differ considerably, but the practice in setting telegraph poles has become fairly uniform; it seems, therefore, most reasonable to determine from this the practice which should be followed for larger but similar structures. This is certainly a better guide than mere guessing. There are special situations where a foundation having a buried platform at its base is more suitable than a prismatic body of concrete; this is especially the case where rock is near the surface or where soft ground overlies a layer of gravel.

DESIGN OF THE TOWER.—If steel towers are designed in accordance with the specification here suggested it will be found that for three large strands pyramidal towers consisting of four angle irons latticed on four sides, anchored by bolts to a square prism of concrete, are most economical. For two high tension lines a considerable distance apart, each of three strands, two triangular bents with their planes parallel to the line, braced together by struts and diagonals, are most suitable, and have been used on several recent lines.

Steel towers so far built for power transmission lines have generally metal from ⅛-in. to ¼-in. thick; they will, therefore, unless frequently painted, be very short-lived. To obtain a durable structure the steel must be embedded in concrete.

In France and Italy towers have been built of reinforced concrete in the shape of octagonal truncated pyramids with a large conical hole running from top to bottom. The reinforcement consists of plain steel rods which are surrounded by wire wrapping. The transmission wires are attached to the shafts by small brackets. These towers are for moderate voltage with small insulators. The brackets are therefore short and the breaking of a wire produces but little torsion.

Fig. 2, herewith, shows a reinforced concrete tower for three strands of 350,000 c. m. for 60,000 volts and 400-ft. spans, which was designed for a proposed transmission line. The double-channel brackets are not directly connected with the steel reinforcement. The torsional strength of the tower mainly depends on that of the concrete; it is therefore moderate. On this account it was advisable to space wires as shown, instead of in equilateral arrangement. Further, to obtain a safe line there must be introduced at intervals guyed towers to which the wires are firmly attached by means of double insulators. The method of guying is also shown in the drawing. The wires should be able to slide easily at the ordinary towers so that these are not exposed to much torsion. The guys of the guyed towers must be attached to the ends of the brackets and run in both directions of the line so as to relieve the towers of torsion and longitudinal forces. The guys are not durable and must be occasionally renewed.

These towers have the following defects: Neither the top insulator pin, nor the brackets, nor the base are directly connected with the steel reinforcement. The steel is arranged in an octagon. For any direction of the overturning forces a part of the steel and most of the concrete is unfavorably situated. The cross-section shows the position of the neutral axis, assuming that the concrete carries no tension. Most of the concrete is on the tension side where it is of no use. Octagonal hollow towers with reinforcing rods are best for moderate voltages where short brackets can be used and for moderate spans which require towers of not more than 40 ft. height above ground. Such small towers do not require a platform base; an enlargement of the diameter where the tower is below ground will give sufficient strength of foundation.

To make a good connection of the steel reinforcement with the top insulator, with the cross arm and with the platform base, if such is required, the reinforcement should be in the shape of angles instead of rods. In this case riveted connections can be made and a much greater torsional strength of the tower can be secured. thus avoiding the use of guyed towers. To secure an economic distribution of the material to resist the overturning forces in the directions normal to and along the line, the steel and concrete should be placed in the four corners of a square or rectangle. A tower with four posts is the logical consequence. For small towers this sub-division of the material is not practicable since the separate members must have considerable size to resist the bending strain due to torsion. For large towers it is most economical and avoids the use of the troublesome core.

Such a tower, as designed for 660-ft. spans, is shown in Fig. 3. It has horizontal struts at short intervals, but no diagonals. The tower may be considered as consisting of two bents normal to the line connected together by longitudinal struts. The two legs of each bent are convex toward the center line giving the tower a concave profile. To avoid bending moments in the legs due to wind pressure and the absence of diagonals, the polygon of the two legs of each bent must be so determined that the legs in each story, if continued, would meet at the center of the wind pressures above that story. This will make the wind strains in the omitted diagonals zero, and bending strains in the posts due to the absence of diagonals are avoided. This is not accurately but approximately true, since the height of the center of wind pressures changes to some extent, but the bending moments in the posts due to wind pressure will be small. The forces acting in the direction of the line arise partly from wind, partly from the breaking of a wire. The position of the center of these forces will vary greatly; they inevitably produce bending strains in the legs if no diagonals are used. The height of the stories and the dimensions of the legs must be so chosen that these bending strains, together with the other strains occurring at the same time, can be safely resisted. The torsion arising from the breaking of a wire at the end of the cross arm produces the largest bending moments in the legs. These are proportional to the height of the stories and inversely proportional to the distance between the legs. The stories may therefore gradually increase in height toward the bottom where the legs are farther apart.

A simple design is obtained if the tower is built so that the four legs are in the corners of squares through its whole height.

The concrete covering of the steel makes the tower as durable as a masonry structure. It greatly increases the compressive strength of the four posts. The concrete in the posts shown takes 4-5 of the compression, the steel 1-5. The amount of steel required is therefore determined by the tension and bending strains in the posts. The bending strains are moderate if the stories are low, and if the wires are so attached to the insulators that they can slide with small friction. The angle lacing on four sides which is necessary if no concrete covering is used is replaced by light tie plates. The maximum tension in the tower legs which mainly determines the cross-section of their steel is considerably smaller than the maximum compression. If the concrete covering were omitted the posts would have to be calculated by the use of a column formula to resist the compression; their section would have to be much larger than that of the steel of the concrete covered posts.

With steel towers the top of the concrete block forming the foundation should be from 6 ins. to 1 ft. above ground. With concrete-covered towers the foundation block can economically stop about 1½ ft. below ground, without thereby materially weakening the foundation. The greater weight of the concrete-covered tower adds materially to its stability wherever the foundation block has considerable horizontal dimensions. For the size of tower shown in Fig. 2 the cost is in many situations reduced by the concrete covering, since the steel saved more than balances the expense of the additional concrete required.

Reinforced concrete towers, such as have been built in France, which are of small size, can be manufactured at a suitable place, transported to the site and erected. The principal advantage of making them hollow is the ease of transportation and erection. Solid towers could only be transported by rail and erected by a heavy derrick. The larger sizes for which four-legged towers are suitable require a good road or railway to transport them. Where these are not available the towers must be built on their site, and then erected. The solid materials, the water and the plant for erection may have to be transported over considerable distances through the fields; this makes the concrete expensive and may make the towers, under unfavorable circumstances, more expensive than steel towers.

The proper general dimensions will vary with size and number of wires, the span used and the amount of ice which must be allowed for. These towers are not suitable for spans of less than 400 ft. if only three large strands are to be carried. Where a large number of strands or wires are to be carried, requiring high and strong towers for short spans they may be used with advantage for much shorter spans. Where but little torsion and small forces acting in the direction of the line must be provided for they are especially suitable, since the four posts will then be exposed to but small bending moments. The stories can then be made high and the posts of small cross section. To reduce the weight of the towers and to facilitate their transportation and handling the prismatic foundation may be made with a large octagonal hole.

NOTES ON THE DESIGN AND CONSTRUCTION OF REINFORCED CONCRETE CULVERTS.

By C. F. Graff, C. E.*

The railway systems of this country are exceedingly cautious in adopting reinforced concrete designs for their standards. A large number of roads, among which are many of the first rank, are building reinforced concrete structures of special designs to suit special conditions, and where such form of construction is plainly the best and most economical in so far as particular cases are concerned. When it comes to standard plans, however, a road of the first class is slow in committing or placing itself on record as approving of, or advocating, this style of construction.

Of course, if a road considers this method of building new or untried, it is right and proper that it act conservatively in the matter of its adoption. A railway structure, subjected, as it usually is, to the heavy traffic of this day, and exposed, as it frequently is, to the often violent

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forces of nature, is not the proper place to experiment as to whether a plain or patented bar, or reinforcement, best serves our purpose; whether or not the embedded metal remains intact under corrosive influences, or if Considere's statement as to the stretching ability of reinforced concrete is correct or erroneous. There is a quite natural tendency amongst the more conservative engineers to afford others the privilege of performing any experiments which are to be done as regards both materials and processes of construction, and the fact that a road does not rashly or hastily adopt any methods which it may consider as not yet having passed

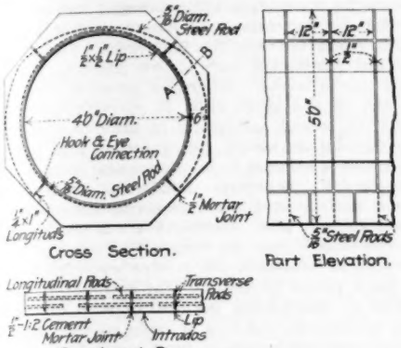


Fig. 1. Design for Reinforced Concrete Pipe Culvert.

the experimental stage is an evidence of its high standing and its realization of grave responsibility.

It should be recognized, however, that this style of building may now be deemed to have satisfactorily passed both experimental and actual tests in practice as to its adaptability, and that, when rational and scientific designing is resorted to, and first-class construction obtained, reinforced concrete is as applicable to, and as advantageous in, railway structures as in any other class of building.

It would seem that the engineering departments of our railways are more deliberate in availing themselves of this construction as applied to culverts and small openings than perhaps any other line of structures. We see quite a number of arch bridges of varying spans going up; retaining walls, bridge floors, round houses, shops, and numerous miscellaneous structures, all of reinforced concrete. Even reinforced concrete ties are now coming into use in this country on a small scale. But culverts built of concrete and reinforced with metal are, generally speaking, conspicuous by their absence. And yet the adoption of this style of construction for box and arch culverts on a system would, in most cases, aggregate a far larger saving than the building of a long-span arch bridge, an unusually high wall, or some other large structure in reinforced concrete, for the simple reason that culverts occur in such numbers on most of our railway lines.

That it is safe to construct concrete arches reinforced with steel, both highway and railway, and of spans from 100 to 200 ft. or more in length, is proven by the comparatively large number already built in this country, now under construction, or contemplated. If, then, it is considered safe to erect long-span and flat arches of reinforced concrete and subject them to heavy railway traffic, why is it not at least equally safe to build culverts of reinforced concrete? If it can be proven, and it certainly can, that such culverts are also more economical than plain concrete, that they are practical of construction and more durable as well, why not build them?

A culvert built of reinforced concrete is not only more economical than one of the plain type, but it possesses greater durability and is a safer structure. Such a culvert will stand up under more severe conditions imposed by traffic and nature alike than one not so reinforced, and if both were subjected to the same test the former would remain intact a far longer period of time.

Every one familiar with maintenance of way matters is aware of the only too common occurrence of cracked concrete culverts. The most frequent cause of failure is the unequal settlement of the foundation under the two ends of the structure, causing ugly, gaping cracks at right angles to its longitudinal axis, and running up the side walls and, indeed, often noticed extending across the intradosal face of the arch. Similar transverse cracks often occur in the invert. Another type of crack, also much in evidence, is one running longitudinally along the center line of invert where such usually has the least thickness, indicating unequal settlement of the side wall foundations. Failures such as alluded to above are only too often apparent to any one walking through and inspecting the opening. It is clear that they not only violate the simple laws of esthetics, but have a serious effect upon the lasting qualities and strength of a structure which is subjected to the well known destructive agency of flowing water and the impact of heavy, moving loads. Contraction and expansion from changes of temperature, as well as shrinkage stresses, have also been known to occasion cracks in concrete culverts, but these causes of failure are not so common as unequally yielding foundations.

Now, if our culvert is reinforced we need not fear these familiar causes of failure to such an extent. If the reinforcement is properly placed the concrete will hold together. It will, in fact, act as a monolith. The culvert, or parts of the same, will be capable of beam action and cracks will not appear so readily as in a plain concrete structure. It follows that far greater durability is assured. Even in putting up culverts of plain concrete and of massive form, the writer has had occasion to resort to reinforcement on account of unusually soft foundations, in two instances during the present year being compelled to reinforce the invert transversely, thus enabling the load to be sustained, not only by the side wall footings, but also by the invert.

A rather common impression seems to prevail among those not experienced in reinforced concrete construction, that it is rendered expensive and cumbersome by the introduction of the reinforcement and the building of more complicated forms. This impression is usually not well founded. It is quite surprising how rapidly and neatly a good form carpenter will put up forms, and whether such forms are plain, straight work, or more or less complicated, makes little difference in the total cost of a concrete job. Also, concerning the placing of the concrete. As regards a culvert of the style shown in the accompanying plans, for instance, it is a fair statement that the extra cost of such work over that involved if the culvert were of the accepted massive type would scarcely be noticeable. The same number of men in the form to distribute, place and tamp the concrete is necessary in either case. The largest additional item of expense caused by the reinforcement is the cost of the steel and this may, without much error, be assumed at from 2½ to 3 cts. laid down on the site of work. The expense of cutting and shaping such steel reinforcement, on work with which the writer has had to do, has averaged about 0.2 ct. per pound, and the handling and placing of same costs in the neighborhood of 0.5 ct. per pound. It is clear that these figures are variable and would not obtain on all classes of work, but, it is believed, that in assuming the cost of the steel bar reinforcement in place at 3.5 cts. per pound no serious error in estimates of costs is introduced, one way or the other. It will be found that, although the aggregate of these cost items arising from the insertion of the steel is no small amount, it is the direct cause of a much larger source of saving on account of the lessened concrete yardage obtained in reinforced designs.

The writer submits herewith some designs of reinforced concrete culverts which were worked up by him during the spring of the present year. In presenting these designs he does not claim originality as they are in general features similar to those brought out by Mr. Walter W. Colpitts, Assistant Chief Engineer K. C. M. and O. Ry., in an admirable paper by him entitled "Calculation of the Stresses and the Practical Design of Structures in Steel-Concrete." The preparation of the designs herewith submitted was undertaken for the specific purpose of comparing the costs of plain and reinforced concrete culverts, both flat top box and arched construction, and for spans up to, and including, 20 ft. These spans cover the sizes of culverts ordinarily built and those of greater span may properly be classed under arch bridges. Though similar in style to the plans presented by Mr. Colpitts, the culvert designs here shown differ from them in the span lengths, in the rise-span ratio employed, and in several other details. Plans and estimates were prepared for flat top box culverts as follows: 4×4 ft., 4×6 ft., 6×6 ft., 6×8 ft., 8×8 ft., and 8×12 ft., the first figure referring to the clear height above top of footing. Arch culverts were worked up for the following sizes: 4×6 ft., 6×6 ft., 8×8 ft., 12×12 ft., 17×16 ft., and 16×20 ft. The 17×16 ft. culvert is intended as a private road crossing but may, of course, be used as a culvert proper by slight and evident changes. All the plans were calculated for heights of bank of both 22 and 40 ft., the weight of filling being assumed at 100 lbs. per cu. ft. A uniform live load of 10,000 lbs. per lin. ft. of track was assumed, 50% added for impact, a safety factor of 4 used on such live load plus impact, and of 2 on dead load. Other values assumed and used were as follows: Ultimate strength of concrete in tension, compression and shear, 200, 2,000 and 400 lbs. per sq. in., respectively. Modulus of elasticity of concrete in compression, 3,000,000 lbs. per sq. in. Elastic limit of steel bar reinforcement, 50,000 lbs. per sq. in. Weight of concrete, 150 lbs. per cu. ft. Corrugated bar reinforcement was employed. The methods of calculation and design are well set forth in the paper above referred to and are based upon Professor Charles E. Greene's discussion of "Parabolic Ribs With Fixed Ends" in his work on "Arches."

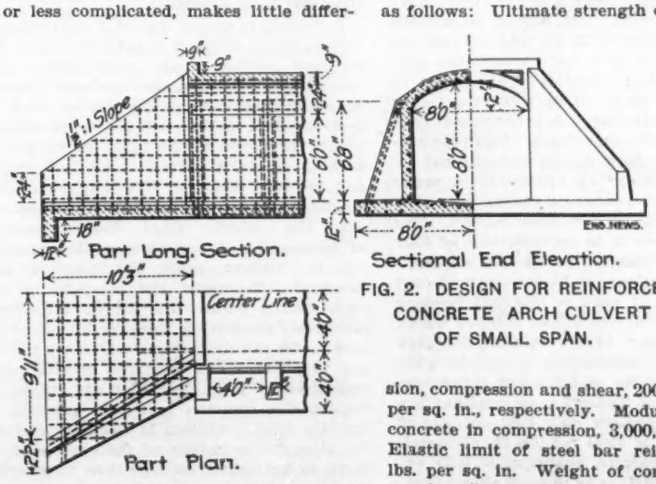


FIG. 2. DESIGN FOR REINFORCED CONCRETE ARCH CULVERT OF SMALL SPAN.

It was found that the assumption of a 40-ft. height of bank resulted in a construction but slightly heavier than that demanded by a 20-ft. bank. So little was the difference that the designs for the lesser height were all thrown out and the conclusion arrived at that the plans here reproduced could consistently be used for all heights of bank up to 40 ft., and, as a matter of fact, a fill of 50 or even 60 ft. would not alter

the same appreciably. It was also found that, so far as quantities are concerned, reinforced concrete arch culverts are more economical than those of the box pattern for any span exceeding 6 ft. The form work for an arch culvert is more expensive than for one of the box shape, but the extra expense is not believed to be large enough to justify the adoption of the latter style of structure for spans exceeding 6 ft.

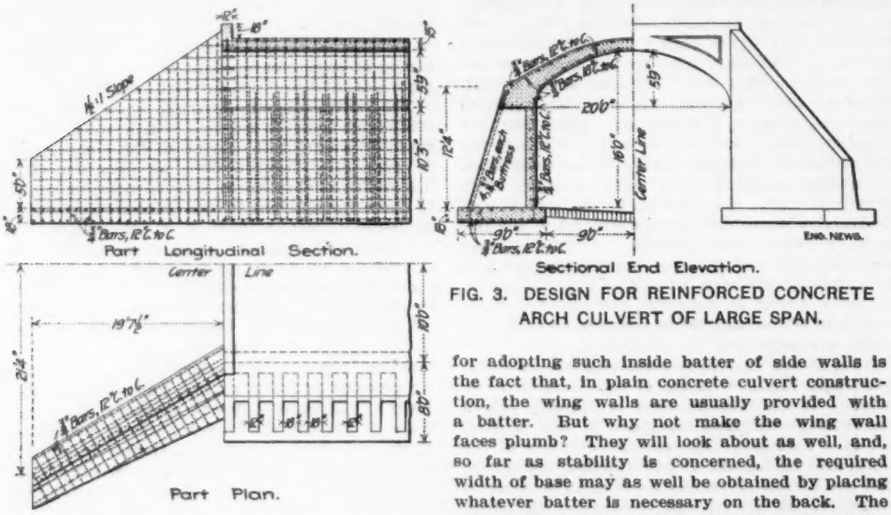


FIG. 3. DESIGN FOR REINFORCED CONCRETE ARCH CULVERT OF LARGE SPAN.

The accompanying Table I contains quantities of concrete and steel per lineal foot of barrel and in each pair of wing walls for some of the culverts worked up. As compared with quantities contained in plain concrete culverts as commonly built and accepted as good practice in this country, a marked difference is seen to exist. Thus, the 8×8 ft. reinforced concrete arch culvert, Fig. 1, contains 1.37 cu. yds. of concrete and 158 lbs. of steel per lineal foot of barrel, which steel, figured at 3½ cts. in place, is equivalent to 0.69 cu. yd. of concrete when the latter is taken at $8.00 per cu. yd. in place. The total equivalent concrete yardage is then 1.37 + 0.69 = 2.06 cu. yds. per lin. ft. of barrel. As against this we have in plain concrete culverts of the same span, and of usual standard designs, from 3 to 4 cu. yds. Also, in this particular culvert, one pair of wing walls is observed to contain 11.22 cu. yds. of concrete and 793 lbs. of steel, or a total equivalent concrete quantity of 11.22 + 3.47 = 14.69 cu. yds. of concrete as against 40 to 50 cu. yds. in ordinary plain concrete construction. A proportional saving holds for the other structures. The pipe culvert plan is similar to a design brought out by Mr. Walter C. Parmley* as applicable to sewer construction. There appears no reason why such a pipe is not suitable as a railway culvert. The drawing Fig. 2 shows it to be composed of four sections and it is intended to be laid similarly to a sewer. The sections, or blocks, may be cast in forms on the site of work or this may be done elsewhere and the concrete blocks shipped where wanted. The circular bars reinforce the pipe greatly while the longitudinal ones tie the abutting blocks together and prevent transverse failure. Inspection of Table 1 indicates that the 4 ft. pipe culvert requires only 0.30 cu. yd. of concrete and 12 lbs. of steel per lin. ft. of barrel, or an equivalent concrete quantity of 0.35 cu. yd. per lin. ft. Comparison as to costs shows that, for small openings, such a concrete pipe culvert can be laid at a considerably lower figure than one of either cast iron or tile pipe.

It will be noticed that the culverts under discussion possess no batter on the inside of side walls but are vertical. The writer does not approve of such batter for the reason that it narrows the water-way where the greatest area is needed to facilitate the quiet flow of the current, and it is unsightly as well. Presumably the reason for adopting such inside batter of side walls is the fact that, in plain concrete culvert construction, the wing walls are usually provided with a batter. But why not make the wing wall faces plumb? They will look about as well, and, so far as stability is concerned, the required width of base may as well be obtained by placing whatever batter is necessary on the back. The same holds true as regards the side walls of the culvert proper. The face should be vertical and a rear batter provided which will be great enough to insure stability.

It is seen that the designs here presented have flat arches, a ratio of rise to span of one to four having been consistently employed except in the 20-ft. culvert. Wherever the headroom is limited, as is so often the case, a flat arch is naturally preferable to a circular one for the reason that a greater waterway is obtained.

The same general method of design as that set forth by Mr. Colpitts in his paper above referred to was made use of in the working up of the designs here discussed and this matter will not here be entered into in detail. Some brief remarks touching on the principles involved would, however, seem pertinent.

Referring to any of the reinforced concrete arch culvert plans shown it is evident that in detailing an arch section of this construction it is not essential to good practice that our pressure line lie everywhere within the middle third of such section as in plain concrete construction. The elastic theory forms the basis for design, and the arch is designed to take combined compressive and bending stresses. We may here allow the resultant pressure to fall considerably outside the middle third limits resulting in subjecting the section to a tensile sress dependent in amount upon the position of such resultant. To assist the concrete in resisting such tensile stress the curved intradosal and extradosal reinforcing bars are introduced, which bars assist the concrete in taking up the stresses due to positive and negative bending moments, respectively. It is clear that our ability to thus neglect the common and safe practice of the "middle third," without in the least endangering the strength or safety of the arch ring, should result in far lighter sections than those ordinarily obtained, and in consequent economy. An inspection of the designs shown proves this to be the case.

The thrust from the arch is transferred to the base by means of buttresses. These ribs or buttresses, together with the thin face wall and base, replace the heavy side walls necessitated in massive culverts and their use results in a considerable saving of material. The side walls are, in fact, constructed very much like ordinary reinforced concrete retaining walls and an idea of the percentages of saving obtained over plain concrete work in such walls may be had by referring to an article by the writer on this matter and recently printed in this journal.* If the foundation is yielding, which must be assumed in the preparation of standard plans, the base will of necessity be made to act as a continuous beam, its lower face being brought into tension under the buttresses and its upper face taking such stress between the buttresses. The longitudinal reinforcing bars shown assist in taking this tensile stress. Where no invert is used, as in the 16 and 20-ft. (Fig. 3) culverts, the base must be spread sufficiently to bring the loading on foundation within our assumed safe limits, and this is effected in an economical manner by introducing transverse reinforcing bars near lower surface of same, thus permitting of cantilever action. If a concrete invert is used, which is the case where the foundations are not firm or able to withstand the erosive water action, it is quite proper to assume that such invert shall assist in transferring the load or arch thrust to the foundation, and this is made possible by the transverse reinforcement near upper face of invert, which face will then be subjected to tension from the upward ground reaction. The intradosal reinforcing bars are continued down the side walls and into the base, thus enabling these walls to withstand lateral earth pressure and permitting a comparatively slight thickness of wall with safety.

In figuring reinforced concrete structures the dimensions resulting from, and demanded by, the theoretical treatment of a design are very often too small to be adapted in practice. It is not prudent, or even safe, to build in concrete as one would build in steel. So much depends upon the manner in which the work is executed, upon weather conditions, the quality and mixing of the ingredients, and upon other rather uncertain factors, that the laying of concrete in thicknesses of less than 9 ins. does not seem desirable so far as general railroad work is concerned. A minimum thickness of 9 ins. has been used by the writer, not only in the plans here discussed, but in all of his other work in reinforced concrete, though the-

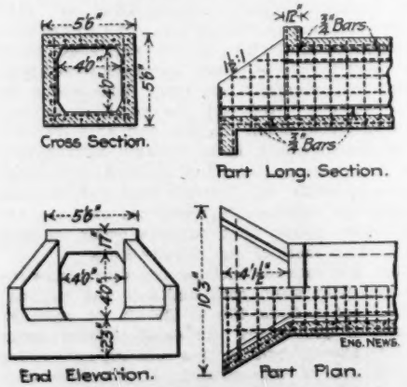


Fig. 4. Design for Reinforced Concrete Box Culvert.

oretical requirements may have demanded far less than this.

No shear bars are indicated in the arches, such being unnecessary. Under uniform loading the vertical shear increases from nothing at the crown to a maximum at the springing, but even near the abutments the shearing resistance of the concrete is large enough to prevent failure by shear when the dimensions here used are adhered to.

Longitudinal reinforcement to take up temperature stresses is freely used. Even though such reinforcement may not always be needed to

*Eng. News, Jan. 5, 1905.

*Eng. News, March 14, 1905.

TABLE I.—SHOWING REINFORCED CONCRETE-STEEL CULVERT QUANTITIES.

Size, ft. in.	Barrel per lin. ft. Concrete, cu. yds.	Steel, pounds.	Paving, cu. yds.	1 Pair Wing Walls Concrete cu. yds.	Steel, pounds.	Paving, cu. yds.	Remarks.	
2 × 0	0.10	6	...	....	....	...	Pipe Culvert	
3 × 0	0.23	10	...	....	....	...	"	"
4 × 0	0.30	12	...	....	....	...	"	"
4 × 4	0.54	61	...	2.38	141	...	Box Culvert Arch	"
4 × 6	0.72	73	...	2.50	128	...	"	"
6 × 6	0.86	116	...	5.16	397	...	"	"
8 × 8	1.37	158	...	11.22	793	...	"	"
12 × 12	2.78	237	...	37.25	1,850	...	"	"
17 × 16	3.70	287	...	51.80	2,579	...	"	" Road Xng
16 × 20	5.00	300	0.66	45.60	2,143	20.2	"	"
16 × 20	5.05	307	...	46.02	2,277	...	"	" Road Xng

provide for these stresses, it will in many cases be of service in preventing transverse cracks in a concrete culvert, which cracks, as previously mentioned, are probably the most common evidences of failure in these structures.

In detailing reinforced concrete box culverts, the cover, base, and side walls may all be assumed to act as simple beams and the method of design is simple and evident.

SOME EXPERIMENTS ON THE STRENGTH OF BRICKWORK PIERS AND PILLARS OF CONCRETE.

By William Charles Popplewell, M. Sc., Assoc. M. Inst. C. E.

The experiments described in this paper formed part of a series of tests carried out by the author and his students upon samples of brick, mortar, brickwork, concrete and ferro-concrete. The experiments upon the larger specimens, including the brickwork piers and the specimens of concrete and ferro-concrete, were carried out in the vertical 750-ton compression testing-machine in the Materials Testing Laboratory at the Municipal School of Technology, Manchester. The elastic tests of the smaller specimens, such as individual bricks, and cubes of mortar and cement, were made in the 50-ton Wicksteed testing-machine in use in that laboratory.

SETTING THE SPECIMENS IN THE MACHINES.—Some of the brickwork columns were built in position, ready for testing, on the lower platen of the testing-machine, whilst others were built outside the machine, on rigid square frames of timber, and were moved bodily into the machine after the proper interval of time had elapsed. Each specimen was set vertically on the lower platen in a thin layer of neat cement. The upper surface, which had been left approximately true by the maker, was then covered with a thin layer of cement, and the upper platen brought down upon it with just sufficient force to render the top surface true. Before bringing down the table a thin sheet of greased millboard was interposed between the metal and the cement to prevent the latter from adhering to the platen, and at the same time to assist in equalizing the stress on the specimen. The specimens of concrete and mortar, as well as the bricks, were set in quick-setting plaster-of-Paris. Both these methods of bedding were found to give fairly uniform distribution of the stress. In nearly all the tests recorded in this paper the compressions of the specimens due to the loads imposed were observed and measured by means of the Martens mirror-extensometer.

METHOD OF CARRYING OUT THE EXPERIMENTS.—In nearly every case the method of carrying out an experiment was as follows: After the bedding had been completed, and before the commencement of the experiment, the Martens mirrors were fixed on the specimen and carefully adjusted. Loads were then imposed, by

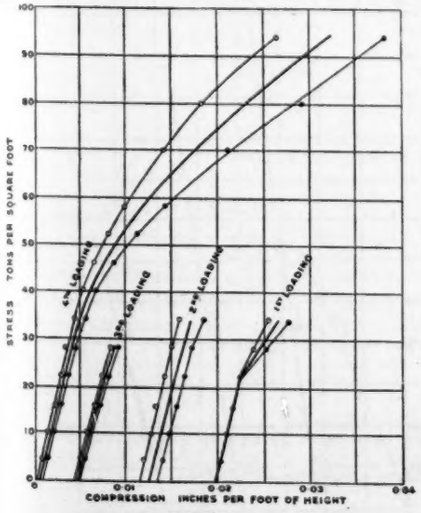


Fig. 4.

uniform increments, and readings were taken on the front and back mirrors after each increment of load. Before reaching the elastic limit of the material the load was removed and the permanent set, if any, was noted. This process was repeated until several sets of readings had been obtained. Then, for the final set of readings, the loadings were continued until the material began to crack, or until the cross-wire of the telescope got beyond the end of the scale. When this point had been reached the mirrors were removed and the specimen was tested to destruction by gradually increasing the load.

RESULTS OF THE EXPERIMENTS.—The results of the experiments are numbered Nos. 1 to 24 inclusive. These numbers refer in most cases to individual experiments; in one or two instances groups of experiments are referred to.

Stress-strain curves have been plotted from the results of the experiments, the stresses being given in tons per square foot and the strains in thousandths of an inch on 12 ins. length of the specimen. For purposes of comparison the same scale has been used throughout, as far

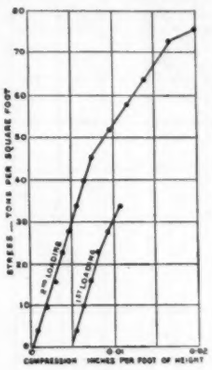


Fig. 1.

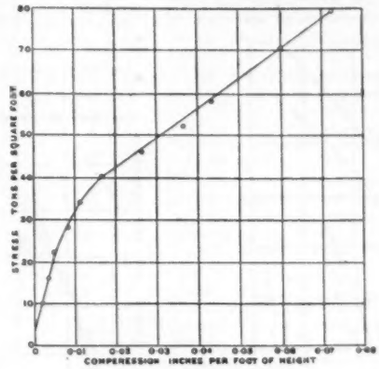


Fig. 2.

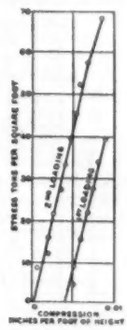


Fig. 3.

as possible. In some cases curves have been plotted from all the sets of readings obtained, separate curves being plotted for the readings taken on the front and back faces of the specimen, and also for the means of the front and back readings. The readings taken on the front face are indicated by small open circles, whilst those taken on the back face are denoted by circular black spots, the mean curve being shown without any indication of the individual points. For the remaining experiments only the mean curves are given.

LIMIT OF PROPORTIONALITY.—For nearly all the materials experimented upon, the compressions were found to be sensibly proportional to the corresponding stresses during the earlier stages of the loading. This is clearly shown by the plotted diagrams. It will be seen that for a considerable period after the commencement of the loading the plotted points lie on a straight line. The point in the loading at which the line ceases to be straight and curvature begins may be taken as the "limit of proportionality." It will be observed that this limit is raised to a higher point after the first loading.

MODULUS OF ELASTICITY.—The value of the elastic modulus or coefficient has been calculated in the usual way, the stresses (S) taken being the differences between upper and lower limits of stress within the limit of proportionality, and as far apart as possible. The corresponding strains (X) were taken as the number of thousandths of an inch compression on a length of 12 ins. Where readings were taken on both front and back faces of the specimen, the mean reading was taken. In the actual experiments, measuring-bars of various lengths were used to suit the dimensions of the individual specimens, but for convenience in comparison the author has reduced all the readings of compression to their equivalents for a uniform measured length of 12 ins.

Calculating from these stresses and strains, the elastic modulus becomes:

$$E = \frac{12{,}000\ S}{X} \text{ tons per sq. ft.}$$

The coefficient so obtained is the ordinary coefficient, or Young's modulus, E, as distinguished from what Unwin calls E^1, which is calculated from strains after the permanent portion or "set" has been as far as possible eliminated. From some of the experiments described, several different values of the modulus have been obtained, these values corresponding to the different successive loadings. It will be noticed that the permanent set is reduced with each successive loading—this reduction being most marked after the first loading—with the result that the modulus increases with each successive loading. This is not strictly true for every experiment in which several sets of readings have been taken, but it represents the general tendency. How far this reduction of set and increase of modulus might be carried by an indefinite number of successive loadings with relatively high stresses it is impossible to foretell, but the experiments appear to show that after two or three repetitions the strains become practically constant.

THE CRACKING-STRESS.—On examining the curves it will be seen that with each successive loading the total strain corresponding to a given stress is reduced, this being probably due to a squeezing together and closing up of the interstices in the material. During the last loading previous to final destruction a point is always reached at which slight cracks begin to appear on the surface of the specimen. In most cases it was found that a warning of the approach of this point was given by slight creaking sounds being heard before any cracks could be actually seen. The load at which this cracking was first detected has been called the "cracking-load," and from it is calculated the "cracking-stress."

Usually very few strain measurements were possible after the cracking-load had been passed, the loads being gradually increased until a maximum was reached beyond which the load could no longer be supported by the specimen. This has been called the "crushing-load" and from it the "crushing-stress" has been calculated. A peculiarity of the plain concrete pillars tested is that they invariably failed completely at the cracking-load. In other words, the specimen collapsed on the first appearance of the minutest crack.

The following are the detailed results:

TEST I.—Pier of common wire-cut bricks set in lime-mortar, 2 parts sand to 1 part lime, and tested 4 weeks after building. Dimensions of pier: 1 ft. 6 ins. by 1 ft. 6 ins., by 3 ft. in height.

Results.

Began to crack with stress of	35.00	tons per sq. ft.				
Badly cracked	"	"	"	47.50	"	"
Crushed	"	"	"	53.00	"	"

With this specimen no attempt was made to take any measurements of the elastic compressions, and the results yielded are simply those of a pier of the most

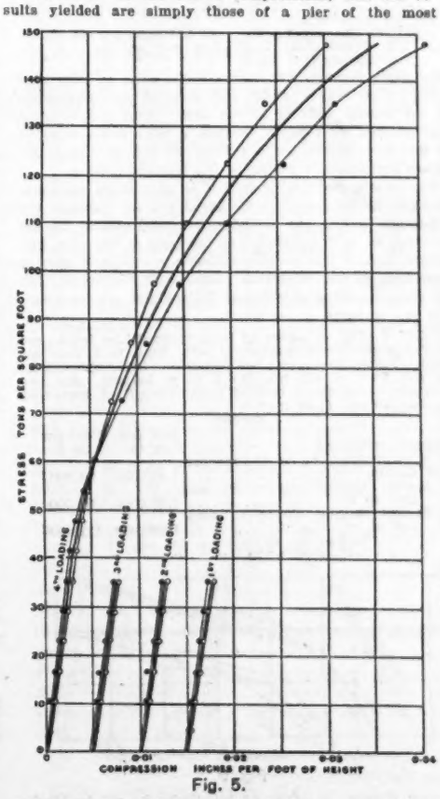


Fig. 5.

ordinary soft bricks set in lime-mortar, and tested only 4 weeks after building.

TEST No. 2 (Fig. 1).—Pier of common wire-cut bricks set in Portland cement mortar 3 parts sand to 1 part cement, and tested 39 weeks after building. Dimensions of pier: 1 ft. 6¼ ins. by 1 ft. 6⅜ ins., by 3 ft. in height. Martens mirrors set on back surface of pier. Measured length, 20 m. (7.88 ins.)

Results.

Elastic modulus:	Lbs. per sq. in.	Tons per sq. ft.
First loading, up to 40 tons per sq. ft.	1,276,000	82,000
Second loading, up to 40 tons per sq. ft.	1,400,000	90,000

The first crack appeared at 63.70 tons per sq. ft. and the pier crushed at 84.30 tons per sq. ft.

When readings are taken on one face only, as in this case, there arises a possibility of error in the calculation of the modulus. The compressions as given by readings taken on one face of the specimen may or may not be the average strains. In most cases there is at least some variation between the compressions on opposite faces. In the present instance it has been necessary to assume the compression to be uniform and equal to that at the back face. That this assumption is within certain limits justifiable is shown by an inspection of the pairs of

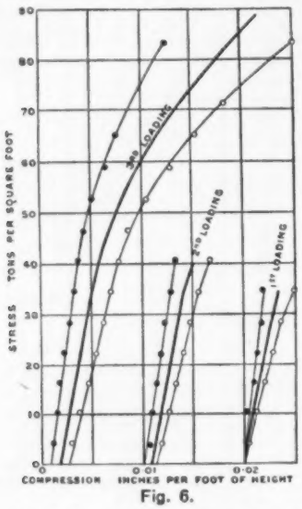


Fig. 6.

curves plotted from the experiments in which both mirrors were used.

TEST 3 (Fig. 2).—Pier of Accrington (Huncoat Plastic) bricks in black lime-mortar. Tested 4 weeks after building. Dimensions: 1 ft. 6¼ ins. by 1 ft. 6½ ins., by 3 ft. in height.

Results.

Elastic modulus:		
800,000 lbs. per sq. in.	51,400 tons per sq. ft.	
Cracked at 78.30 tons per sq. ft.		
Crushed " 95.50 " " " "		

The measurements of compressions were in this case taken on the whole length, and included the compression of the cement bedding at the ends. This measurement was effected by reading through a microscope attached to the lower platen on to a finely-divided steel scale attached to the upper platen of the testing-machine.

The elastic modulus arrived it is an illusory quantity, because the compressions measured are not those of the brickwork alone, but include the compressions of the packing, or setting-material at the ends of the pier. The compression of this packing-material is relatively greater than that of the brickwork alone, with the result that the strains used in calculating the modulus are too great, and the modulus is too small.

TEST 4 (Fig. 3).—Pier of blue Staffordshire bricks set in Portland cement mortar, 3 parts sand to 1 part cement. Tested 39 weeks after building. Dimensions: 1 ft. 6½ ins. by 1 ft. 6¼ ins., by 3 ft. in height. Martens mirrors set on front face of pier. Length of measured portion, 20 cm. (7.88 ins.)

Results.

Elastic modulus:	Lbs. per sq. in.	Tons per sq. ft.
First loading, up to 40 tons per sq. ft.	1,420,000	91,300
Second loading, up to 30 tons per sq. ft.	1,470,000	94,500
Second loading, 30 to 55 tons per sq. ft.	1,880,000	121,000
Cracked at 69.10 tons per sq. ft.		
Crushed " 97.70 " " " "		

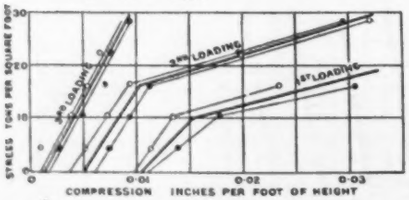


Fig. 9.

TEST 5 (Fig. 4).—Pier of brindle-bricks set in black lime-mortar, tested 12 weeks after building. Dimensions: 1 ft. 6⅛ ins. by 1 ft. 6¼ ins., by 2 ft. 11 ins. in height. Martens mirrors set on both front and back faces of pier. Measured length, 20 cm. (7.88 ins.)

Results.

Elastic modulus:	Lbs. per sq. in.	Tons per sq. ft.
First loading, up to 22 tons per sq. ft.	1,360,000	87,400
Second loading, up to 34 tons per sq. ft.	1,350,000	86,800
Third loading, up to 22 tons per sq. ft.	1,350,000	86,800
Fourth loading, up to 28 tons per sq. ft.	1,520,000	97,700
Cracked at 100.00 tons per sq. ft.		
Crushed " 164.00 " " " "		

This was the first of a set of six piers, built in pairs, of the same kind of bricks but with three different kinds of mortar. The three kinds of mortar used were black lime-mortar, composed of lime, sand and ground cinder; Portland-cement mortar, made with 3 parts of sand to 1 part of cement; and Lias-lime mortar, composed of Lias-

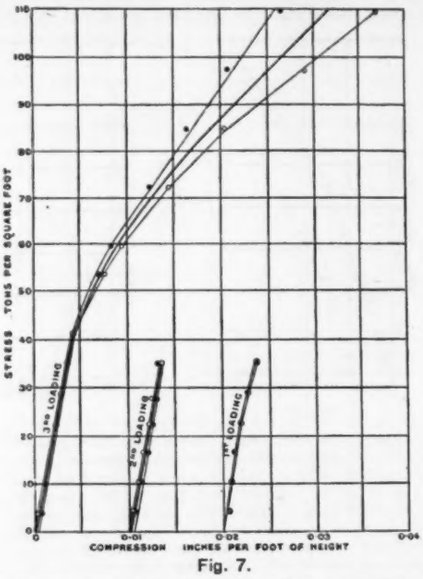


Fig. 7.

lime and sand. The piers were tested in two sets of three piers each, made with the three mortars, at intervals of approximately 3 months and 6 months after building. All four piers built with lime-mortar and cement-mortar gave excellent results, but those built with Lias-lime mortar were less satisfactory; this is probably accounted for by the bricklayer having mixed the mortar too long before it was to be used, with the result that it must have been partially set before it was laid on the bricks. Nos. 6, 7, 8, 9 and 10 form the remaining piers of the same series.

TEST 6.—Brindle-brick pier set in black lime-mortar, tested 25½ weeks after building. Dimensions: 1 ft. 6 ins. by 1 ft. 5⅞ ins., by 2 ft. 11 ins. in height. Martens mirrors set on both faces of the pillar. Measured length 20 cm. (7.88 ins.)

Results.

Elastic modulus:	Lbs. per sq. in.	Tons per sq. ft.
First loading, up to 28.97 tons per sq. ft.	2,605,000	167,500
Second loading, up to 28.97 tons per sq. ft.	2,508,000	161,200
Third loading, up to 28.97 tons per sq. ft.	2,520,000	162,000
Fourth loading, up to 28.97 tons per sq. ft.	2,330,000	149,800
Slight crack heard at 109.70 tons per sq. ft.		
Cracked throughout " 147.20 " " " "		
Crushed at 185.00 tons per sq. ft.		

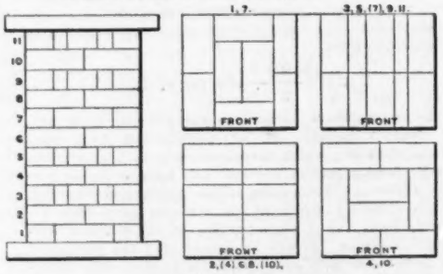


Fig. 10.

TEST 7 (Fig. 6).—Brindle-brick pier set in Portland-cement mortar (3 to 1), tested 12 weeks after building. Dimensions: 1 ft. 6⅛ ins. by 1 ft. 6 ins., by 2 ft. 11 ins. in height. Martens mirrors set on both front and back faces. Measured length, 20 cm. (7.88 ins.)

Results.

Elastic modulus:	Lbs. per sq. in.	Tons per sq. ft.
First loading, up to 16.26 tons per sq. ft.	1,940,000	125,000
Second loading, up to 28.45 tons per sq. ft.	1,930,000	124,000
Third loading, up to 40.70 tons per sq. ft.	1,880,000	121,000
Cracked at 132.00 tons per sq. ft.		
Crushed " 169.00 " " " "		

TEST 8 (Fig. 7).—Brindle-brick pier set in Portland-cement mortar, tested 26 weeks after building. Dimensions: 1 ft. 6 ins. by 1 ft. 6 ins., by 2 ft. 11 ins. in height. Martens mirrors set on both front and back faces of the pier. Measured length, 20 cm. (7.88 ins.)

Results.

Elastic modulus:	Lbs. per sq. in.	Tons per sq. ft.
First loading, up to 28.81 tons per sq. ft.	1,980,000	127,000
Second loading, up to 28.81 tons per sq. ft.	2,050,000	132,000
Third loading, up to 41.25 tons per sq. ft.	1,895,000	122,000
Began to crack at 90.20 tons per sq. ft.		
Crushed at 161.30 tons per sq. ft.		

TEST 9 (Fig. 8).—Brindle-brick pier set in Lias-lime mortar, tested 12 weeks after building. Dimensions: 1 ft. 6⅛ ins. by 1 ft. 5¾ ins., by 2 ft. 11 ins. in height. Martens mirrors set on both front and back faces of the pier. Measured length, 20 cm. (7.88 ins.)

Results.

Elastic modulus:	Lbs. per sq. in.	Tons per sq. ft.
First loading, up to 10.25 tons per sq. ft.	543,000	34,900
Second loading, up to 16.48 tons per sq. ft.	624,000	40,100
Third loading, up to 23.60 tons per sq. ft.	688,000	44,200
Began to crack at 38.10 tons per sq. ft.		
Crushed at 118.70 tons per sq. ft.		

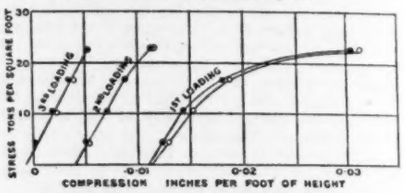


Fig. 8.

TEST 10 (Fig. 9).—Brindle-brick pier set in Lias-lime mortar, tested 26 weeks after building. Dimensions: 1 ft. 6 ins. by 1 ft. 6¼ ins., by 2 ft. 11 ins. in height. Martens mirrors set on both front and back faces of the pier. Measured length, 20 cm. (7.88 ins.)

Results.

Elastic modulus:	Lbs. per sq. in.	Tons per sq. ft.
First loading, up to 10.15 tons per sq. ft.	396,000	25,500
Second loading, up to 16.25 tons per sq. ft.	598,000	38,500
Third loading, up to 28.50 tons per sq. ft.	638,000	41,000
Cracked at 40.70 tons per sq. ft.		
Crushed " 101.70 " " " "		

All the brickwork piers experimented upon in the foregoing tests (Nos. 1 to 10) were built by working bricklayers, who freely used their own discretion as to the bond and other details of construction. This was done so that the work might be as nearly as possible the kind of brickwork usually met with in ordinary engineering practice. The actual bond used was in the main that shown in Fig. 10.

The results of the tests of brickwork piers are summarized in Table I.

TESTS 11, 12, 13 and 14 (Fig. 11).—Single bricks, similar to those used in the construction of the piers.—

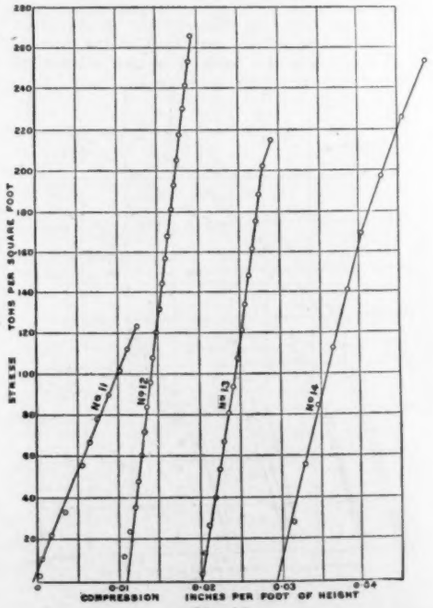


Fig. 11.

The elastic tests were made with the bricks placed on end, with the Martens mirrors attached. The crushing tests were made with the bricks set on their proper beds in plaster-of-Paris.

The curves plotted in Fig. 11 refer to the four kinds of bricks tested. The principal results obtained from these tests are given together in Table II.

TESTS 15 and 16 (Fig. 12).—Cubes made from the lime-mortar and cement-mortar used in building the piers.—These experiments are not satisfactory, as the results of tests of cubes of a mortar are not comparable with the results of loading the same material when used

to form the joints of brickwork, except perhaps as regards the elastic modulus. This is not only by reason of the difference in dimensions, but also because the material resulting from setting in the form of a relatively large cube under no pressure is not the same as that obtained from the setting which takes place in thin layers between bricks under some small pressure.

The curves obtained from these experiments are shown

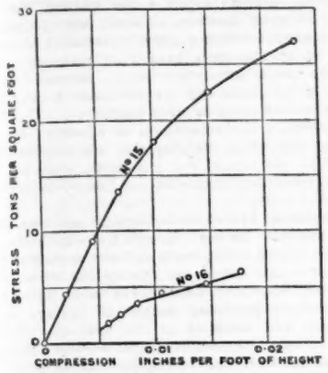


Fig. 12.

in Fig. 12, and the results are summarized in Table III.

TESTS 17 to 24 (Fig. 13).—Cubes and columns of Portland-cement concrete, and pillars of reinforced concrete.—The curves obtained are shown in Fig. 13, and the principal results are given in Table IV.

Of these, Nos. 17, 18, 19, 20, 22 and 23 are experiments taken from a series carried out by the author in connection with the construction of the new storage-sheds for the most recently-constructed of the docks for the Manchester Ship Canal Co. The sheds are constructed on the Hennebique reinforced concrete system. Nos. 21 and 24 are respectively a plain concrete and a ferro-concrete column formed of the material used in the con-

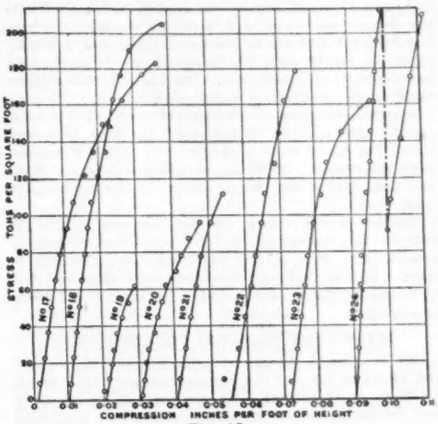


Fig. 13.

struction of a highway bridge in Rochdale, on the Hennebique system. The material of these specimens of concrete and ferro-concrete varies in respect of both the kind of ballast used and the make of the cement. In all cases the ballast was sufficiently small to pass through a ⅝-in. or ¾-in. mesh, and was in some cases pebbly gravel and sand obtained in excavation for the dock, while in others it consisted of broken stone and sand. The cubes were 1 ft. in length of side; the columns were all 12 ins. by 10 ins. in cross-section, and 3 ft. in height. The ferro-concrete columns were of the standard Hennebique construction, having four bars of steel 1¾ ins. in diameter placed near the corners of the pillar and running from top to bottom. At the commencement of the experiments the load was equally distributed on steel and concrete alike, but, owing to the greater compression of the concrete as compared with that of the steel, as the test proceeded the steel carried more and more of the load until the specimen began to fail from the buckling of the bars. This buckling is partly prevented by the lateral tying together of the bars with wrappings of thin round steel placed at frequent intervals. The better results in the case of No. 24 as compared with those of Nos. 22 and 23 are in great measure due to closer spacing of the bindings and more secure fastening to prevent them being pulled open by the buckling of the bars. Where several values are given for the elastic modulus, they refer to the values as calculated from the readings taken during the successive loadings. The curves plotted in Fig. 13 represent the means of the back and front readings taken from the last loading.

CONCLUSIONS.—The results of the experiments upon the brickwork appear to lead to the following conclusions:

(1) Up to loads considerably in excess of those used in actual practice the strains are sensibly proportional to the stresses.

(2) Each of the materials experimented upon possesses a fairly definite elastic modulus, under ordinary loads.

(3) With repetition of the load the strain is found to diminish, until, after three or four repetitions, it becomes sensibly constant, possibly owing to the squeezing together of the particles and the closing up of the interstices. This diminution of the strain causes a small increase in the modulus.

(4) At loads considerably in excess of working-loads, proportionality of strain to stress gradually ceases. The point at which this occurs may reasonably be called the "limit of proportionality."

(5) The elastic properties of brickwork, as well as its ultimate strength, appear to depend less upon the bricks than upon the quality of the cementing material.

(6) In all cases the best results are obtained where the mortar employed not only provides a highly elastic bed for the bricks, but has the property of adhering to the bricks in their vertical joints, thus knitting the whole into a homogeneous material.

(7) It is reasonable to suppose—although the experiments upon this point were hardly complete enough to warrant a hasty generalization—that the more nearly the elastic coefficient of the mortar approaches that of the bricks, and the more uniform the thickness of the joints, the more uniform will be the stress upon the bricks, and consequently the stronger the brickwork.

(8) The diagrams show that with the method employed for setting the specimens in the machine a very uniform distribution of the stress is obtained.

TABLE I.—SHOWING RESULTS OF TESTS OF BRICKWORK PIERS.

No.	Kind of Bricks.	Kind of Mortar.	Weeks after Building.	Approximate Limit of Proportionality. Tons per Sq. Ft.	Cracking Stress. Tons per Sq. Ft.	Crushing Stress. Tons per Sq. Ft.	—Elastic Modulus.— Tons per Sq. Ft.	Lbs. per Sq. In.
1	Common wire-cut	Lime	4	....	35	53	.....	.....
2	" "	Portland cement	39	25	64	84	82,000 91,000	1,276,000 1,400,000
3	Accrington	Black lime	4	24	78	98	[51,400]	[800,000
4	Blue Staffordshire	Portland cement	39	55	69	98	91,300 94,500 121,000	1,420,000 1,470,000 1,880,000
5	Brindle	Black lime	12	22	100	165	87,400 86,800 86,800 97,700	1,360,000 1,350,000 1,350,000 1,520,000
6	"	"	25¼	40	110	185	167,500 161,200 162,000 149 800	2,605,000 2,508,000 2,520,000 2,330,000
7	"	Portland cement	12	35	132	169	125,000 124,000 121,000	1,940,000 1,930,000 1,880,000
8	"	"	26	30	90	161	127,000 132,000 122,000	1,980,000 2,050,000 1,895,000
9	"	Lias-lime	12	10	38	119	34,900 40,100 44,200	543,000 624,000 688,000
10	"	"	26	10	41	102	25,500 38,500 41,000	396,000 598,000 638,000

TABLE II.—SHOWING RESULTS OF TESTS OF BRICKS.

No.	Kind of Brick.	Dimensions. Inches.	Elastic Modulus. Lbs. per Sq. In.	Cracking Stress. Tons per Sq. Ft.	Crushing Stress. Tons per Sq. Ft.
11	Common wire-cut (Manchester)	8¾ x 4⅛ x 3	1,760,000	87	264
12	Accrington (Huncoat Plastic)	8¾ x 4⅛ x 3	3,160,000 (up to 36 tons per sq. ft.). 5,920,000 (from 36 tons to 200 tons per sq. ft.)	118	250 (mean of three tests.
13	Blue Staffordshire	9 x 4⅛ x 3	4,430,000 (0 to 100) 5,280,000 (100 to 200)	82	356
14	Blue Brindle (Staffordshire)	8⅞ x 4¼ x 3	2,830,000 (up to 160 tons per sq. ft.)	204 (mean of nine tests).	485 (mean of nine tests)

TABLE III.—SHOWING RESULTS OF TESTS OF CONCRETE CUBES.

No.	Composition.	Dimensions. Ins.	Elastic Modulus. Lbs. per Sq In.	Cracking Stress. Tons per Sq. Ft.	Crushing Stress. Tons per Sq. Ft.
15	Black lime-mortar (lime, sand, and ground cinder), 28 weeks old	4 x 4 x 4	352,000	31.8	31.8
16	Portland-cement mortar (3 sand, 1 cement) 24 weeks old	4 x 4 x 4	131,500	10.0	10.0

TABLE IV.—SHOWING RESULTS OF TESTS OF PILLOWS OF CONCRETE.

No.	Material.	Age, Weeks.	Approximate Limit of Proportionality. Tons per Sq. ft.	Cracking Stress. Tons per Sq. Ft.	Crushing Stress. Tons per Sq. Ft.	—Elastic Modulus.— Tons per Sq. Ft.	Lbs per Sq. In.
17	Concrete cube, dock gravel and finely-ground cement (5 to 1)	13	65	183	211	105,000	1,633,000
18	Concrete cube; dock gravel and ordinary cement (5 to 1)	34	95	196	225	164,000	2,550,000
19	Concrete column; dock gravel and ordinary cement (5 to 1)	15	40	70	70	113 000	1,750,000
20	Ditto	27	40	101	101	118,000	1,830,000
21	Concrete column; broken sandstone and Portland cement (5 to 1)	53	75	141	141	99,000 120,000	1,540,000 1,860,000
22	Reinforced concrete column; dock gravel and ordinary cement (5 to 1)	15	140	120	210	113,000 142 000	1,760,000 2,210,000
23	Ditto	27	109	211	236	169,000	2,630,000
24	Concrete same as No. 21. Transverse links twisted	53	190	211	343	307,000 (mean of five tests)	4,780,000 (mean of five tests)

REPORT OF THE CHIEF ENGINEER OF THE ISTHMIAN CANAL COMMISSION.

There was given out for publication at Washington, on Dec. 29, the Annual Report of the Isthmian Canal Commission for the year ending Dec. 1, 1905. Most of the material contained in this report has already been made public and has been presented to our readers in the recent addresses of Secretary Taft and Chairman Shonts, printed in our issues of Nov. 9 and Nov. 23. As an appendix to this report, however, there is printed the first official report of the Chief Engineer, Mr. John R. Stevens, and while this is dated as far back as Sept. 30 last, it nevertheless contains very much matter of especial interest to our readers not hitherto made public. In the following we have reprinted those portions of Mr. Stevens' report which we deem of most direct interest to engineers. It should be borne in mind, of course, that the conditions referred to by him are those existing three months ago and not those of the present day:

Isthmian Canal Commission,
Department of Construction and Engineering,
Ancon, Canal Zone, Isthmus of Panama, Sept. 30, 1905.

Sir: I have the honor to submit the following as a general report of operations and conditions affecting the departments of construction and engineering for the three months ending Sept. 30, 1905, or the first quarter of the present fiscal year.

Although my appointment as chief engineer of the Isthmian Canal Commission was of July 1, 1905, I did not arrive on the Isthmus until July 26 to assume active charge of the operation of the department of construction and engineering.

My first steps were, naturally, to become sufficiently acquainted with the then existing situation to enable me to determine whether any changes in organization,

methods of operation, or personnel seemed necessary. A close observation soon made it clear to me that an abnormal state of feeling existed among many of our employees, manifesting itself in lack of interest, absence of harmony, not only between different departments, but between divisions of the same department. The general expression, implied if not directly indicated, was one of discouragement, amounting almost to indifference. This situation had arisen, I judged, from several causes, among them being the sudden changes in executive officers, with the consequent usual crop of senseless rumors and natural fear of the results of a possible epidemic of disease; but more than any other cause seemed to be the grounded impression that the policy which was being pursued in carrying out the work was not a successful one, and that only failure could be expected.

This last assumption was not at all warranted, as, while undoubtedly mistakes had been made, as there always will be in carrying out work of such magnitude no matter who may be at the head of its departments, there is always the chance for an honest difference of opinion, both as to methods and results.

I found very much good work done and in progress as to sanitation, repair and building of quarters, construction of sewers, water-works, and other necessary adjuncts. The work on the canal prism proper was largely in the nature of experiments, while the data thus gathered were not of such a character, in my opinion, that correct and conclusive results could safely be deduced from them owing to several causes, among these causes being poor equipment, poor tracks, unsuitable dumping grounds, and piecemeal work generally. All these causes, added to an undoubted lack of force and a discouraged feeling among the personnel, made all attempts to produce good results an impossibility.

My first efforts were directed to outlining such an organization of the department as best seemed to me to enable the situation to be clarified, simplified and placed on such a basis that the duties of every official, of whatever rank, should be so clearly defined and his consequent responsibility so clearly apparent that only a negligent or wilful interpretation of its rules could produce unsatisfactory conditions, and these merely temporary. The short trial that has been made with this organization has convinced me that with some slight modifications it is well fitted to, and will, accomplish what was intended.

Another and very important step was to secure the confidence of employees, not only personally but along such lines as would induce faith in themselves and in the work they were enlisted upon, and to make them feel that their interests were one with the Commission and with the work. There can be no doubt but what this has been accomplished to a remarkable degree, and that better and quicker good results will be evident from day to day.

Very few changes in the personnel of officials and employees have occurred, and the average ability and effectiveness, outside of our common labor, would be well up to the standard which obtains in the United States if more discretion had been exercised in many cases in making selections and appointments. Conditions of climate and environment are so different from what most of our men have lived under in the past that necessarily unusual care must be taken in the filling of positions in all grades of employees.

DIVISION OF LABOR AND QUARTERS.

This branch has charge of the hiring of all grades of employees and of assigning them to the various departments as they may be needed, of providing and assigning them quarters, of supervising and directing the proper furnishing and the care of such quarters, and of keeping a general personal record of all employees. It also directly handles all hotels and mess houses, and has general charge of all buildings on the Canal Zone belonging to the Isthmian Canal Commission.

DIVISION OF MUNICIPAL ENGINEERING.

This division has charge of the design and construction of water-works and sewers, not only in Panama and Colon, but over the entire Canal Zone wherever such are needed, with also the care and maintenance of same, with the construction and repair of roads and work of like character.

Of its more important work it carried out during the three months ended Sept. 30:

Panama Water-Works.—At present date 55% of the entire work of installing this plant is completed.

Ancon Reservoir.—Was practically completed, all the necessary concrete work being done, and it is expected to be put into service Oct. 15.

Colon Water-Works and Sewers.—The forces at that point have been engaged in the construction of a temporary dam at Brazos Brook, which will supply Colon with water until a permanent reservoir is completed, and as the temporary plant is a part of the general scheme of furnishing this water none of the work which is now being done on it will be lost.

Ancon Hospital.—1,430 lin. ft. of all sizes of pipe laid, about 20% of the work authorized.

La Boca.—The supply-pipe line to Ancon reservoir has been tapped, and 1,000 ft. of water pipe laid connecting with the former La Boca supply line, thus furnishing La Boca with water for its present needs.

Culebra Water Supply.—2,500 lin. ft. of pipe has been laid, and 47 house connections made. Work on Comacho dam is well under way, a supply track having been laid from the Panama Railroad to the dam site, 1⅛ miles in length, and 25 acres of clearing at the site of the dam been completed, about 50%. Excavation and grading work on the reservoir is now in progress.

Gorgona.—All work on the reservoir excavation is completed. 1,000 cu. yds. of excavation has been done, and 10,038 lin. ft. of water pipe laid, and 11 house connections established. 4,000 ft. of temporary supply track has been laid and a large amount of other necessary work done.

Panama Sewers.—Work on the sewerage system of Panama is progressing in fairly good shape, and at present date 62% of the total work as approved is done. During the three months of time there was put in 13,065 lin. ft. of sewers, and a vast number of house connections.

DIVISION OF BUILDING CONSTRUCTION.

This division is charged with the preparation of plans and estimates for and the construction and repair of all buildings on the Canal Zone. During this period plans and estimates for 45 structures have been completed and work done on a large number of plans which are still uncompleted.

Repairs have been authorized to 517 buildings, 195 of which have been completed and 2 demolished.

Work has continued on buildings already under construction and a number of new buildings have been put under construction; not as many as desired, owing to the serious lack of material.

During this period requisitions were made for 4,042,487 ft. B. M. of lumber, and but 1,878,496 ft. was delivered, nearly all of which was consumed in repair work.

Up to July 1, 1905, the construction of 210 buildings had been authorized. Since that time some 85 more have been authorized; and of this total number 120 are now in course of erection, and about 175 have not been begun owing to a variety of causes, principally lack of material.

A detailed list of all work of this division during the period would be too long for this report, but there is hardly a spot on the Canal Zone where it has not done work of more or less importance, ranging from heavy repairs, amounting in many cases to a reconstruction of large and important buildings, to the thousand and one smaller repairs necessary and incident to the rehabilitation of the buildings of the Commission, and this work has very largely been done under extreme stress, arising from the necessity for proper housing and caring for thousands of men, from inefficient colored so-called "skilled" labor, and from lack of material.

The division is now, however, so organized and supervised, and is beginning to receive material in large enough quantities (although not properly classified as yet), as to encourage me in the belief that its effectiveness is beginning to be felt in a marked degree.

Very much, however, remains to be done, as it is a tremendous task to provide for the proper housing, in view of the very rigid requirements of the sanitary officials and the very liberal and proper policy of the Commission, of the army of men required in the execution of this work under the conditions and in this latitude.

The entire force of this division has ranged from 1,700 in July to 2,350 in September.

MECHANICAL DIVISION.

The work of this division before July 31 largely consisted in repairs to old French and Belgian locomotives and French 6-yard side-dump cars, of which a large number had been repaired for service and a large amount of money spent on same. This policy was at once discontinued, and only enough of such work ordered done since July to enable necessary equipment to be provided for such work as was deemed advisable to continue.

The force account of this division was: June 30, 1,017; July 31, 905; August 30, 745; September 30, 726.

The work of the division has covered a multitude of items, such as the erection of 200 steel flat cars, 24 dump cars, 7 steam shovels, 4 earth spreaders, general repairs to 10 locomotives, repairs to a lot of small dump cars, also to a large lot of steam drill boilers, and heavy and light repairs to almost every class of machine in the Canal Zone. It has made 164,000 lbs. of iron and 11,300 lbs. of brass castings, and has made and repaired machines and tools in large numbers for every division and department on the work.

It has under order a large list of new equipment, as 300 steel flat cars, 120 new locomotives, 800 wooden flat cars, 31 steam shovels, 6 earth spreaders, 6 heavy unloaders, 12 ballast plows, 4 locomotive cranes, 12 water columns, 24 dump cars, 1 100-ton steam wrecker, and 2 60-ft. steel turntables.

COLON DIVISION.

Covers all work of technical engineering and construction pertaining to the canal from Bohio to the Caribbean Sea, and the work during the period has consisted of surveys, borings, dredging, repair and construction of floating equipment, and a lot of track work, the latter now transferred to the Panama Railroad Co.

In detail the technical engineering work has consisted of general surveys to locate the existing canal, the Panama Railroad, diversion channels, and of topography of the country covering a possible relocation of the railroad. Many soundings have been made to properly chart the canal, particularly at its entrance, and test borings in the canal and the diversions to a depth of 45 ft. have been made in large numbers.

Up to Sept. 1 the supervision of all wharf and dock work was also under the charge of this division, during which time two timber and pile docks, each 800 ft. in length, were nearly completed and placed in service at Cristobal.

One of the old French ladder dredges has been in continuous operation during this period, dredging the channel at the mouth of the canal and at the piers and slips at Cristobal and Colon, and during the three months 160,000 cu. yds. of material have been removed and handled in self-propelling barges, an average distance of 2 miles, and deposited on the west side of Limon Bay. As a result, in addition to the work in Colon piers, a channel has been excavated to a minimum depth of 25 ft., extending from Colon Point a distance of 3,500 ft. up the canal.

Orders have also been placed for one large ocean-going tug and for 11 steel barges, all of which are badly needed. Contracts have also been made for 2 modern dipper dredges, delivery to be completed about May, 1906. One of these dredges is for service at Colon and the other at La Boca, on the Pacific side, as the keeping open of both of these ports is now directly dependent on the only two dredges which we have been able to put into service, same being old French dredges which we have repaired. Work has all been delayed on this division more or less owing to lack of material of all kinds.

LA BOCA DIVISION.

Covers the work on the canal proper from the Pacific Ocean to Miraflores, and the operation of a small machine shop and marine ways for the repair of floating equipment at La Boca.

Surveys of the canal proper, soundings, and tidal observations have been taken, and some borings are now in progress at the harbor entrance and across the entire valley of the Rio Grande.

During the entire period one of the old French dredges has been at work deepening and enlarging the channel leading to the steel pier, in deepening the basin, and in dredging in front of the new 800-ft. timber pier which is just being completed. 145,000 cu. yds. has been removed from the basin and 111,000 cu. yds. from the channel, a total of 256,000 cu. yds. in the three months. All this material has been moved in barges to the west of Naos Island, a distance of 4 miles.

In front of the new pier there is a depth of 24 ft. at low spring tide, with a depth of 120 ft.; in front of the railroad steel pier a depth of 26 ft., with a width of 165 ft.

Soundings taken along the channel entrance from the steel pier out to the crest of the bar on Aug. 1 indicated a least channel depth of but 15 ft. at low spring tide.

The basin in front of the steel pier was dredged in December, 1904, and during that time soundings showed a least depth of 26 ft., with an average of 27 ft. On May 30 there was an average of 20.2 ft., on June 30 an average of 18.7 ft., on July 31 an average of 16.8 ft., and during August it was necessary to dredge the entire basin and channel to permit ships to unload and load at the steel pier.

CHAGRES RIVER SURVEYS.

During the period a force of engineers has been engaged in taking topography on the line of the proposed Gatuncillo tunnel and of the proposed Dique open cut. An estimate, with maps and profiles of the open cut and tunnel, has been completed.

DIVISION OF METEOROLOGY AND RIVER HYDRAULICS.

This division was reorganized on Sept. 1, and is now, I believe, in shape to efficiently perform the work assigned to it.

The sections used since the French company established observations on the Chagres are now being resurveyed and all tabulations needed will be made immediately.

The necessary technical instructions covering the care and operation of self-recording rain gages and current meters have been given the different observers, and already a marked improvement is shown in the uniformity and accuracy of reports. A permanent rating station has been established at Bohio, so that the experiments can be quickly and efficiently performed.

The question of sedimentary matter and of evaporation is receiving proper attention, and valuable data in these directions will be collected.

These three months in this division have been largely utilized in careful and systematic preparation, though much actual work has been accomplished. The installation of stations and the technical training of the men has gone forward until now it is believed that systematic and correct reports and results will be obtained.

CULEBRA DIVISION.

This division, extending from Bas Obispo to Miraflores, covers what is known as the "Culebra cut," as, under whatever plan or type of canal is finally adopted, an enormously heavy land or dry cutting, so called, must be executed. And to successfully carry out this great project necessitates not only the employment of the most effective and modern machinery, but also as nearly perfect an organization as can be devised; and with these conditions met the question of cost per unit will be disposed of.

The material found in this proposed cutting, as shown by actual work performed and by numerous borings and pits, is very much mixed in character, ranging from a red and yellow clay, through several varieties of rock of different degrees of hardness, to a hard trap rock. Altogether the cut is what would be called a rock cut, inasmuch as a very large percentage of it must be loosened by blasting—in fact, about all of it—to enable economical handling.

Since American control of the work, up to August, 1905, the principal efforts seem to have been in the nature of experiments, looking possibly to ascertaining by actual practice the proper methods of handling the material; and to this end modern steam shovels were gradually introduced, until on August 1 there were 11 of these steam shovels at work, served by such equipment as could be picked up on the work as left by the French, in the nature of small Belgian locomotives and dump cars.

These were operated on lines which, by the utmost stretch of the imagination, could not be termed railroad tracks. Thousands of yards of material were loaded and hauled by this equipment, over these tracks, to land dumps, the latter improperly located and in character unsuited to the end in view. Doubtless the original purpose under which this work was undertaken was a wise one, but the long continuance of it and the utter absence, as far as could be learned, of any thought or attempt to plan a systematic method of handling the work as a whole, would seem to be open to grave criticism.

As soon as possible this situation was thoroughly considered, and as any purpose which this work was designed to serve seemed to have been accomplished, it was immediately determined to close down, as you were then advised, all actual excavation work as far as possible, only continuing, after readjustment, such as seemed to be necessary to conform to some intelligent plan for future operations and to enable an organization to be held together.

Accordingly, five shovels and a corresponding amount of train and other service were laid off, and such of the men as it was thought wise to retain were assigned to other duties, occasion, however, being taken to drop from service such as were not considered competent or were otherwise disqualified, and a few of them were returned to the United States.

Then was begun the reconstruction of such old tracks as it seemed would be useful to the work and the construction of new tracks properly built, all looking to as complete a system as possible to handle the transportation of the immense amount of material certain to be moved under any plan of the canal.

All available forces have, therefore, since August 15 been engaged in preparatory work, as indicated above, and no effort has been made to excavate and dispose of any material excepting as rendered necessary to carry out this outlined policy.

At the same time a careful study of conditions, both in the cut and at probable dump of waste grounds, has been made and still continues, and as a result a large amount of transportation and auxiliary equipment has been ordered, and on receipt of same it is expected that track and other conditions will be such that the actual work of excavation can be gradually instituted and increased by proper development until the maximum output of material can be reached.

Observation and record seem to indicate that work can be successfully prosecuted during the dry season—about four or five months each year—and that during the remaining months—seven or eight—the constant rains will unavoidably cause such loss of time, due not only to cessation of work during actual rainfall, but from the effects of it in the cut and on the dumps, that it is seriously doubted whether during more than one-half of such rainy months work can be successfully carried on. In other words, our actual working year will not be one of twelve months, but of about eight or nine months.

The question of plans and methods of carrying out this particular piece of work is very largely dependent on how much is to be done, as, in common with everything in connection with the question of building the canal from ocean to ocean, comes up the handicap of the type of canal that will be built, and until this most important matter is decided no complete and intelligent plans can be adopted, and all work and plans previous to such time will be merely tentative.

Large increases have been made in the force of laborers on this division since July, yet a comparison of pay rolls does not indicate a similar increase. The total June force account was 2,612; the September force account 3,382. The June pay rolls, on a gold basis, were $97,213; the September pay rolls, on a gold basis, were $94,634; and the percentage of force working on tracks to the total number was in June 31% and in September 64%.

The first important work which should be done is the double tracking of certain parts of the Panama Railroad, over which, as far as now can be determined, a vast amount of the waste material from this cut must be transported. Coincident with this work should be the preparation of proper dump grounds, local yards, etc.

The problem of the Culebra cut is one of transportation (including disposal) pure and simple. The material can be loaded with reasonable promptness, but the crux of the proposition is to haul and dispose of it. As can be readily seen, the place and manner of disposition depends entirely on whether a plan of canal is adopted which will require the use of large quantities of material in its construction or whether such a plan is adopted that an unhampered choice in the plans for its disposal can be made. And as the gift of prophecy is withheld from us in these latter days, all we can do now is to make such arrangements as may look proper as far ahead as we can do.

A large amount of necessary surveys looking to the locating of proper dump grounds along the lower Chagres River have been made and are still under way. Surveys and data for the location of rock crushers, etc., have been made and many others for various purposes.

The general office, or "administration building," so called, in Panama, being so utterly unsatisfactory, both in size, general arrangement, and in its sanitary features, orders were issued for the construction of new offices at Culebra and Empire for the use of the department of construction and engineering, the auditor, and the disbursing officer, together with the proper quarters for the necessary employees.

Plans were prepared accordingly for such offices, and in September the work of construction was begun on them, and it is hoped that by the end of the present current year the clerical forces of these departments will be properly housed in the new location, where work can be done under much more cheerful and sanitary conditions than at present.

Taking the proposition of the construction of a canal through the Isthmus of Panama as a whole and as a business undertaking, as far as its construction is concerned there does not seem to be any reason why it can not be successfully accomplished. There is no element of mystery involved in it. No problem now apparent (I refer to purely physical problems) but what can be successfully solved—the problem is one of magnitude and not of miracles; although the time required and the consequent cost will be dependent upon the kind of canal to be built to a far greater extent than has been, I fear, appreciated.

The good results of the work of our very efficient sanitary department have become already so apparent that it is believed the question of health is already assured. The climate is tropical, but my experience leads me to believe it is no more of a handicap than it would be to similar work for a distance of 50 miles from the Gulf of Mexico in any of our Southern States.

The very liberal and wise policy which the Commission is carrying out in its care of its employees and in its treatment of them in every way must, after patient and careful selection, result in a personnel entirely capable of producing good results.

The question of common labor is a very grave one, not in regard to quantity, but quality. We are employing now colored laborers from the West Indian islands, and some Colombians from Cartagena and adjacent country, and it is all very expensive labor even after making the proper allowance in rates of pay. As compared with the best common labor in the United States, I doubt if their efficiency can be rated at more than 33%. Still this efficiency can be raised, and an improvement is already noticeable. A plenitude of laborers, prompt methods of payment, the proper amount of well-cooked food suitable to their needs and desires, and a more careful selection of foremen and superintendents will eventually, it is believed, raise this standard of labor in a most marked degree.

Reference to our white employees has been made. There should be no great difficulty in securing the services of all necessary, with the inducements offered and the nature of the work. It would seem that this work offers many inducements, particularly to young men, that are offered nowhere else in the world. The policy which a very large proportion of our American press has adopted and in many cases is still pursuing, of scattering broadcast any irresponsible, senseless, and wholly untrustworthy rumor in regard to health and other conditions here has, of course, had its effect. But as nine-tenths of the men who come here from the North with an honest purpose to work become, through correspondence, our advertising agents, it is believed the truth will prevail and an ample supply of efficient employees be secured and retained.

In regard to the necessity for additional legislation or changes in rulings of present legislation:

As I have already indicated quite strongly to you, I do not regard the application of the civil service act as necessary or warranted, and so far believe its workings have hindered rather than helped this work.

The application of the eight-hour law is very unfortunate, and I recommend such legislation as may be necessary to take this project from under its scope.

The final audit of all expenditures in carrying out this work should rest with the Commission, through its auditor, and all methods and rules governing its expenditures should be established by it, and it alone.

A thorough business administration, unhampered by any tendency to technicalities, into which many of our public works sometimes drift, is absolutely necessary; and such an administration honestly and energetically carried out will be the best guaranty of the successful completion of this project. There are obstacles enough to be encountered and overcome which are unavoidable, without creating unnecessary ones.

This department should be allowed for expenditure for the balance of this fiscal year—from October to June, 1906, inclusive—including payments for material and equipment already ordered and that to be ordered, payment for which may be due before the end of the fiscal period, and for pay rolls and other necessary items, $9,200,000.

THE PANAMA RAILROAD.

This railroad, completed some 55 years previous, had, by reason of its peculiar location, subject to no competition, and consequently free to do as it pleased, been allowed to lie still, apparently, for years, making no progress or improvements toward modern advancement. The world had moved and it had not, neither in personnel, equipment, methods, nor otherwise.

Business had very largely increased, but neither facilities nor methods had kept pace, and as near a state of paralysis existed as it is possible to conceive. Part of this condition arose from lack of equipment, terminal and line facilities, and much from a lack of organization and a proper comprehension on the part of the management as to the real situation. The larger part of its limited freight equipment was tied up under load—some of it had been for months. No adequate system of car accounting or tracing was in effect, and while passenger-train movement was fairly good, freight handling had about come to a stop. About the only claim for good work heard made was that there had been no collisions for some time. A collision has its good points as well as its bad ones—it indicates there is something moving on the railroad.

The completion of the setting up and getting into service of the first 200 of the 500 lot of flat cars which had been purchased by the Commission was hastened, but the very heavy handicap of the necessary use of the few and antiquated locomotives and cars remained, and it does still. Changes in personnel of officials were made, and a start at modern methods of car handling was inaugurated, and marked improvement in handling business is already apparent.

The condition of the property, aside from the track, was and is bad, apparently no attempt having been made for a number of years even to keep up ordinary repairs on terminals or floating equipment, with the natural consequence that the piers and docks, as well as boats, were hardly serviceable. The repairs on them are now under way, also strengthening road bridges to enable them to carry safely the new locomotives and other rolling stock, orders for which were placed by the Commission early in the year. Work is in progress of rebuilding entirely the telegraph and telephone lines, which were practically out of service.

The nature of the traffic has complicated the handling of the business of the railroad to such an extent that an extremely low cost of handling can never be arrived at. All of the canal business moves from terminals to interior points, resulting in a very light average through train tonnage and a very large empty-car haul, and these factors, coupled with a heavy-grade road and extremely light power, resulting in small trainloads and large train mileage, will keep operating expenses high as compared with those of roads operating under more favorable conditions in regard to above as well as with cheaper labor. Still, correct methods, better supervision, and modern rolling stock will improve matters very much, although time will be necessary to show a very marked improvement.

The railroad has for some time past been operating a commissary, or supply store, at Colon, furnishing a high-grade line of food and other necessary supplies to its employees. To enable its benefits to extend over

the employees of the Commission branches have been established at several points along the line of the canal, open to all employees of the Commission under restrictions and arrangement by the use of properly guarded coupons.

Hotels and eating houses have been established at different points under similar restrictions and guard, open only to employees, and the result has already been so very beneficial and the satisfaction among our employees so great that this move is justly regarded as a very long step toward the solution of the problem of providing proper food at reasonable prices to all classes. Thus one of the most serious problems met in the past, and the one trouble which has undoubtedly caused more dissatisfaction, and justly so, is being met and it is believed will be successfully solved.

Following is a statement of expenditures for the period the quarter ended Sept. 30, 1905, covering the items of construction and engineering, general service accounts, and Panama water-works, this statement, however, not giving the cost of material and supplies:

Account.	July 1 to Sept. 30, 1905.
Office chief engineer	$27,234.48
Manager labor and quarters and corrals	49,068.19
Bureau water-works, sewers and roads	951.10
Bureau meteorology and river hydraulics	3,672.67
Canal construction	315,812.29
Machine-shop expenses	215,568.55
Zone highway improvements	18,022.81
Street improvements, Panama	5,266.68
Construction of water-works and sewers	135,673.61
Construction and repair of buildings	285,343.51
Total	$1,056,613.89

All of which is respectfully submitted.

Jno. F. Stevens, Chief Engineer.

RAILWAY GRADING, DITCHING AND BANK BUILDING MACHINES.

A class of machine which is of great importance in railway construction and improvement work is the spreader car, which is used for spreading and leveling material dumped or plowed from cars for widening banks or for ballasting new tracks to be laid adjacent to that on which the spreader car is run. The car can as a rule be adapted also for forming and cleaning ditches, trimming the ballast slope, and removing snow. Machines of this sort are included in the equipment of nearly all important railways, and are used also in railway and other contract work. Wherever they are employed they effect a great saving in time and cost of work which would otherwise have to be done by scrapers and teams or by gangs of shovelers. One special machine of this type is capable of not only leveling off the material, but also of building up a bank parallel with and higher than the track on which the machine is run, and this is often of special advantage on grade reductions, widening for additional tracks, and similar work, while it can also be used for the other purposes noted above. This particular machine is built by the O. F. Jordan Co., Railway Exchange Building, Chicago, and the elevating wing attachment for building banks, which is one of its special features, was invented by the late Mr. A. Torrey, when Chief Engineer of the Michigan Central Ry., who applied it first to a Jordan spreader car for use in double tracking and grade reduction work on the Michigan Central Ry. about three years ago. The Jordan machine is adapted for construction work as well as maintenance, and is used not only by railways, but also by railway contractors, while four have been purchased by the U. S. Government for work on the Panama Canal.

The Jordan spreader car, which is illustrated by the drawing Fig. 1, and the view in Fig. 2, consists of a heavy flat car surmounted by an open framework to which are attached the cylinders, hand hoists and other mechanism for raising the wings, etc. It is 36 ft. long and 9 ft. 6 ins. wide, with a height of 14 ft. over all. Its weight is about 30 tons. On each side is a vertical post A sliding between vertical guide timbers, B B, and having a movement of 42 ins. This is operated by compressed air cylinders C of 16½ ins. diameter and 42 ins. stroke. Attached to this post by heavy hinges is a plate or wing D to which the main wing, E, 28 ft. long, is pivoted by a bolt F. At G is a small wing which throws the material clear of the ties and is sufficient to move earth or ballast far enough back to clear the pilots of engines or steps of passenger cars.

The two large wings are of 2-in. plank faced on each side with ¼-in. steel plating. There is also

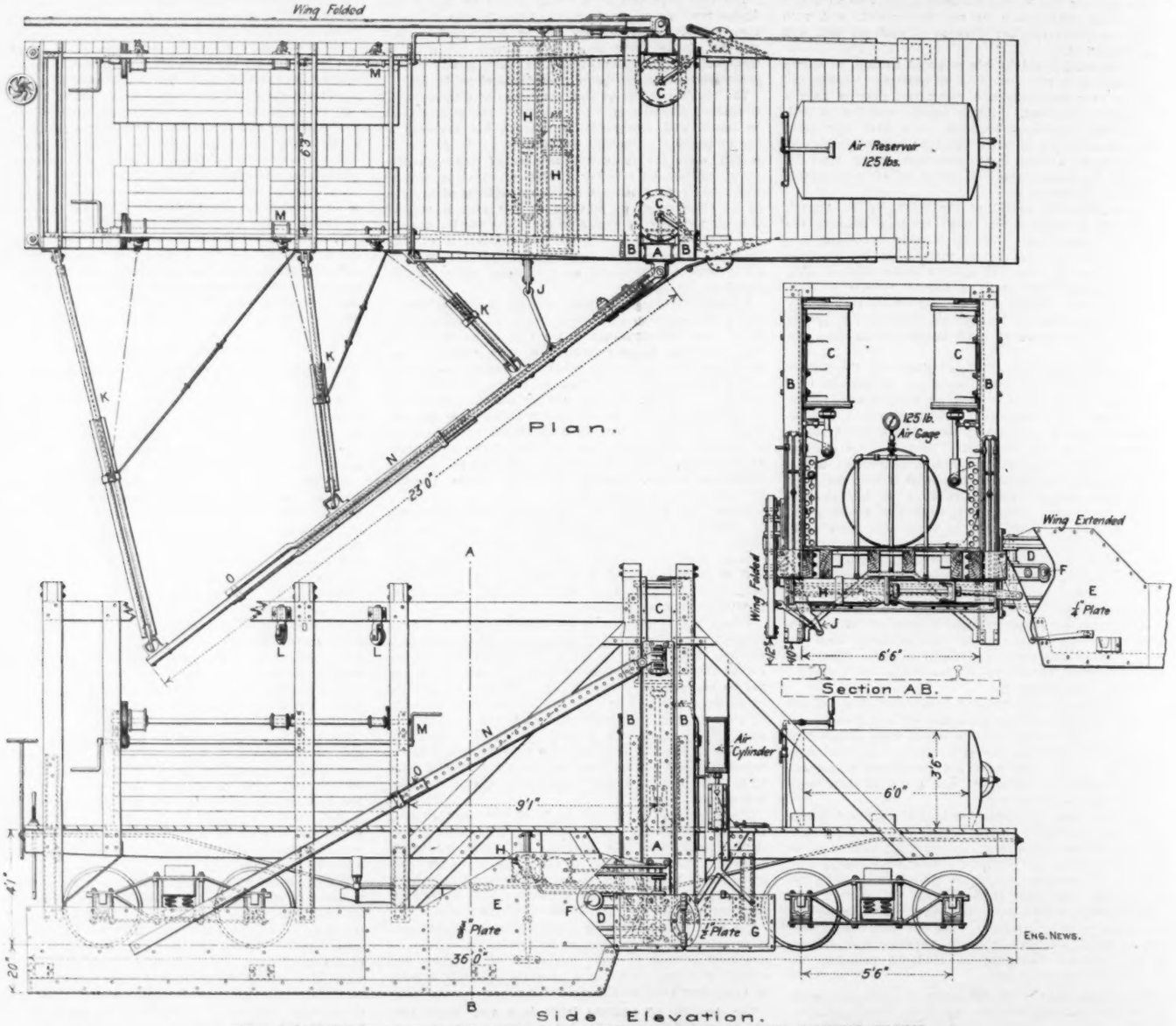


FIG. 1. MACHINE FOR SPREADING AND LEVELING MATERIAL, AND RAISING BANKS.
The O. F. Jordan Co., Chicago, Builders.

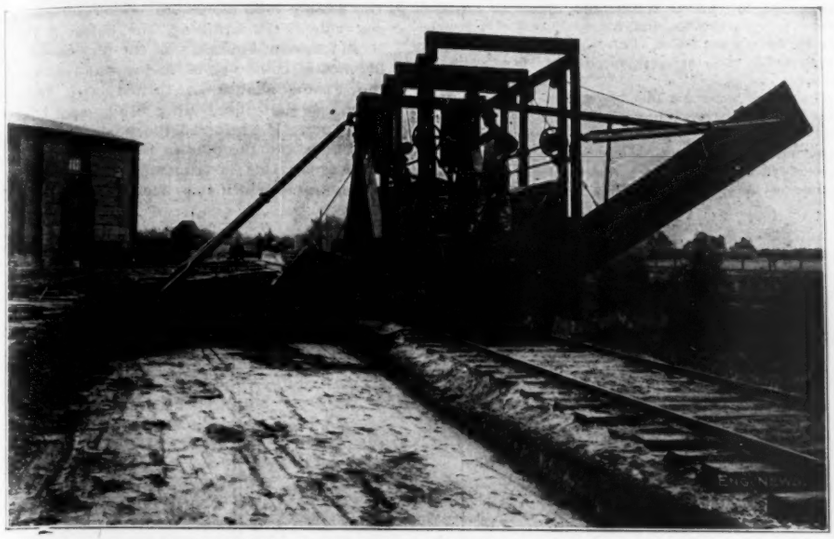


FIG. 2. REAR VIEW OF SPREADING AND LEVELING MACHINE.

an angle iron or shoe ¾ × 6 ins. on the bottom and under the lower edge of these wings. The small wing G is of ½-in. steel plate. The main wings are moved in and out by horizontal cylinders H under the car, and in order to allow for a vertical swinging motion of the wings jointed lever connections are required between the piston rods and wing, as shown at J. The wing is held in position by a set of steel braces K, which are raised and lowered by chains passing over the pulleys L L to the hand hoist M. To the end of the main wing is attached the arm N, whose upper end is carried by the sliding post A. This arm is adjustable in length to suit the varying inclination of the wing; for this purpose it is made in two sections with a pin or bolt joint at O.

In Fig. 2, which is a rear view, one wing is horizontal and is grading a roadbed surface to a depth of 23 ins. below and 17 ft. from the rail. The other wing is inclined outward and upward, in the position for elevating material to form a bank. This view also shows the two positions of the wing bracing. Fig. 3 is a front view of the first machine in the act of building a bank. This machine (already mentioned) was somewhat crude, and the wing was operated by hand gears instead of by power.

In building a bank, when a sufficient amount of earth or gravel has been plowed off the construction trains, the car is first run with the wing so inclined as to throw the material up, as shown in Fig. 3. The car then makes another run with the wing raised and set horizontally so as to level off the bank at the required height. The main wing can cut to a depth of 23 ins. below or 16 ins. above the top of rail, the vertical travel of its post being 39 ins. It can build a bank to a height of 6 ft. above the rail. Fig. 4 shows a cross sections of the machine with the elevating wing in position.

For clearing snow from the tracks the wing can be raised and inclined at such a position as to clear the snow from the slopes of cuts, or to throw it out when it has been piled up between the tracks. When the machine is to be used for ditching or for sloping banks, the large wing is taken off and a ditcher or sloper is attached to the hinge on the sliding post. When ballast is distributed by center-dump cars, a plow may also be fitted under the machine to level off the ballast and to throw it out over the rails to the ends of the ties.

Mr. M. Woolsey, engineer and superintendent of the Kahl Construction Co., informs us that his firm finds the machines very useful and efficient in general railway work. Any ordinary material is easily handled. As to building a bank higher than the track, however, he believes that only light loads could be hauled in the dump cars, as with 5-yd. cars it is not easy to pull them out of the dirt unless the machine has spread the material to the lowest point possible. The speed of running the spreader depends upon the condition of the track and the engines used, but the machine can spread anything that two locomotives can pull it through. With a single light engine, as generally used, from three to four runs are required to spread one train load from a wide shoulder. About 15 miles an hour is as fast as it is practicable to handle the machine. With good material, and the shoulder not wider than 10 ft. from the rail, a 30-ton engine can easily spread 1,000 cu. yds. per day. The crew consists of an engineman and fireman on the locomotive, and two men on the spreader where the wings have to be taken in frequently, so as to clear trains on track. Mr. W. L. Seddon, Chief Engineer of the Seaboard Air Line Ry., states that in leveling or spreading earth the machine is run at from two to ten miles an hour; three men are required, in addition to the engine crew.

ON THE POSSIBLE USE OF POWDERED FELDSPATHIC ROCK AS A FERTILIZER.

The Office of Public Roads in the Department of Agriculture has been, for many years, carrying on investigations of the physical characteristics of rocks used in macadam road construction. It is now well known that the most important quality of a rock for road building is its binding power, which it has been found varies greatly in rocks even of the same type and class. In the course of the investigation of this quality a great number of samples have been ground, both wet and dry, in ball and pebble mills. It appears that in the case of rocks which have binding power the dust undergoes more or less decomposition under the action of water. Quartzite, for example, which is not appreciably acted on by water, has no binding quality, while many of the complex silicates, such as the feldspathic rocks, are more easily acted on. In the case of these complex silicates the bases are set free by the action of water and an estimation of the alkali has furnished a measure of the rate and extent of the action.

Dr. Allerton S. Cushman, who has had charge of these investigations, has shown that the mere leaching of the rock powder with water does not remove by any means all of the alkali set free by the decomposition, as it is held by some sort of absorptive power in the more or less decomposed slimes. It has been found necessary to use an electrolytic process for separating the alkali set free by the action of water. In the cases of many rocks the decompositions went so much further than it had been expected they would that Dr. Cushman was led to make the suggestion that the potash contained might be directly available as fertilizing material. Undoubtedly in nature potash is supplied to the soil by the slow decomposition of certain of the crystalline rocks; some of the granites run as high as 5% and over, in potash, and feldspathic dikes are known running as high as 15%. The

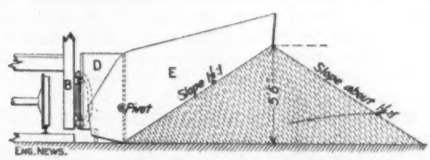


Fig. 4. Position of Wing when Building Bank.

question arose as to what extent the natural process could be hastened by fine grinding of these rocks, both wet and dry. Agricultural chemists have long known that the addition of ground gypsum and of lime to a soil exerted a beneficial action by increasing the availability of the potash locked up in certain of the soil constituents. It is now suggested that the fine grinding of the potash-bearing feldspathic rocks as the possible source of available potash is an interesting field of inquiry. Under the stimulus of the cement industry the art of fine grinding has made tremendous strides, and it is now possible to consider the commercial feasibility

FIG. 3. MACHINE BUILDING OR RAISING BANK (5 FT. HIGHER THAN TRACK UPON WHICH THE MACHINE STANDS).

of grinding rocks to as fine powders as 200-mesh at a comparatively small cost. The imported salts which are used exclusively as potash fertilizers are at present selling upon the valuation of about 3½ to 4 cts. per lb. of available potash, f. o. b. at ports of entry. It is possible that by grinding feldspar, together with limestone or with gypsum, and with the possible addition of ammonium salts, the potash can be made sufficiently available to compete in price with the imported fertilizers. Dr. Cushman is careful to point out, however, that he does not claim that this problem is solved, but that in order to put it to the test other investigators who have the facilities for making large-scale experiments will have to become interested in the investigation.

In 1887 a Scotch agriculturist conducted successful experiments, in which he used Norwegian feldspathic rock ground to 120-mesh powder in comparison with sulphate of potash. He found that he obtained a higher yield with turnips fertilized with ground feldspar than when treated as usual with a soluble salt. Interesting experiments have also been made at the Maine State College and the Colorado Agricultural Experiment Stations which showed that ground feldspathic rock can be successfully used in fertilizing oats and other grain.

Many state laws which control the sale of fertilizers are based upon the belief that unless potash is soluble in water to the extent that it can be freely leached out it is unavailable as a fertilizer, and it is therefore provided that mixed fertilizers must contain a certain percentage of soluble potash. Dr. Cushman's experiments would seem to indicate, however, that potash is, to a very considerable extent, available even if it is not soluble in water in the ordinary sense of the term.

The question of the actual extraction of potash from crystalline rocks has exercised the minds of many chemists. It is by no means an impossible problem, but up to the present time no process has been evolved which has been found to be commercially successful. Dr. Cushman has not at any time claimed to have developed a commercial method for extracting potash from rock. In the laboratory it has been found possible to continually extract this potash merely by the continued action of wet grinding with subsequent removal of the potash in an electrolytic cell, but the cost of such a process on a large scale would render it impracticable. It is to be hoped that these interesting laboratory investigations will be followed up by more extended experiments in plant feeding, so that the practical value of the suggestions made may be tested.*

ELECTRIC TRACTION BETWEEN CAMDEN AND Atlantic City on the Pennsylvania Railroad has been definitely decided upon by that railway, and contracts for the equipment have been let. The following particulars of the equipment of the line are given us by the General Electric Co., who will supply the electric machinery. The line in question is not the present main line from Camden to Atlantic City, but utilizes the double-track Cape May division from Camden by way of Woodbury to Newfield (30 miles), and thence to Atlantic City a connecting line which is to be changed from single track to double track. The total distance is 64 miles (as against 59 miles by the main route). In addition, the electric equipment is to be installed on a further section of the Cape May line, from Newfield to Millville (10 miles). The current supply will be by third rail, except from Camden to Woodbury (8½ miles) and from Newfield to Millville (10 miles), which sections are to be fitted with overhead trolley wire. The supply will be direct current, following established types. Multiple unit trains are to be run, composed of cars each equipped with two 200-HP. motors (type GE-69) controlled by the Sprague-General Electric multiple unit control. The motors are similar to those now being built by the General Electric Co. for the New York terminal equipment of the New York Central & Hudson River R. R. A fast and frequent service is planned. The initial installation will provide for a 3-car train every 15 mins. between Camden and Atlantic City, running at maximum speed of 55 to 60 miles per hour. Half-hourly trains between Camden and Millville (40 miles) by two-car trains, and 10-minute single-car trains between Camden and Woodbury, are also provided for by the present plans. Full service under these plans requires 58 cars, each equipped with two motors as stated.

The power house for the line will be located at Camden. Its generating equipment consists of three 2,000-KW. Curtis steam-turbine dynamos, generating three-phase alternating current at 25 cycles. Current will be transmitted at 33,000 volts pressure to seven substations outside of the power house, one being located at Millville for supplying the Newfield-Millville section and the other six directly on the Camden-Atlantic City line. The total substation capacity is 11,000 KW., in 750 KW. units. The direct current voltage is 650. The rotary converters are arranged to start from the alternating side, by means of taps on the step-down transformers. The contract, involving about three million dollars, calls for completion of the work by July 1, 1906.

*Further, and more technical, information regarding Dr. Cushman's studies of this general subject is given in a ten-page pamphlet by him, entitled "A Study of Rock Decomposition Under the Action of Water," being Circular No. 38, Office of Public Roads, U. S. Department of Agriculture, Washington, D. C.

A STRAIGHT-LINE INSTRUMENT FOR TRISECTING AN ANGLE.

By F. T. Llewellyn,* Assoc. M. Am. Soc. C. E.

There is a function of all trisected angles which forms the basis of a simple and accurate instrument for performing their trisection.

In Fig. 1 let B A C be any angle, and A F, A E its trisectors. Make B A equal to C A, and draw the line B C. Make A D and A G equal to A E or A F, and draw D E and F G. Draw A J perpendicular to B C. Produce A E to H, on line B H perpendicular to B C. Then

$$H E = 2 \times A B.$$

To prove this, note that triangle B D E is similar to A E B, and triangle A E J is similar to triangle H E B. (The latter will be obvious; the former may be shown thus:

A D E + B D E = 180° = A E F + A E B;

But A D E = A E F;

∴ B D E = A E B.

Then in triangles B D E and A E B, the angle at B is common, and angle B D E = angle A E B, hence angle D E B = angle E A B, and the triangles are similar.

Note also that D E = 2 × E J. Then, by similar triangles,

D E : B E :: A E : A B,, or D E × A B = B E × A E

H E : B E :: A E : E J, or H E × E J = B E × A E

$$\therefore D E \times A B = H E \times E J$$

but, as D E = 2 E J, we find A B = ½ H E.

The instrument for utilizing this fact to trisect any angle comprises only three parts: a right-angled frame, a ruling stick, and two crossheads or slides. The Frame, Fig. 2, consists of two guides set perpendicular to each other, with a diagonal brace for stiffness. The vertical guide may conveniently be about twice as long as the horizontal guide. The Ruling Stick, Fig. 3, has a hole at one end, and another hole towards the middle not farther away than the length of the vertical guide, the stick being conveniently nearly twice this length, with its ruling edge set back slightly so that a line can be drawn along it concentric with the two holes. The Slides, Fig. 4, have projecting pins which fit into the holes in the Stick and allow same to travel in the Frame, the end hole along the vertical guide and the middle hole along the horizontal guide. For convenience in handling, the holes in the Stick should be countersunk and the pins upset there but not of course so as to prevent rotation. As the Frame should be turned with the guide down, so that the Ruling Stick may come near the paper. If preferred the holes may be put in the Slides and the pins in the Stick.

To apply this instrument: Let B A C, Fig. 1, be any angle which it is desired to trisect. Ma

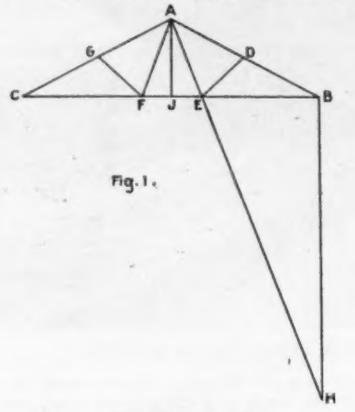
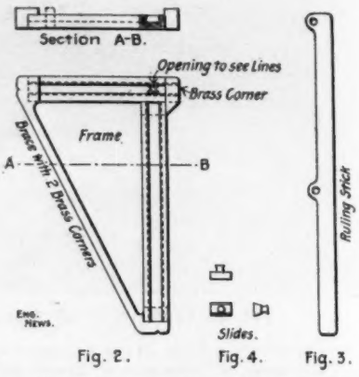


Fig. 1.

Fig. 1. The Trisected Angle.



Figs. 2 to 4. Parts of Angle-Trisector.

B A and C A equal to exactly half the distance between centers of holes in Stick, which is constant. Join B C, and from B draw B H perpendicular to B C. Place the Frame so that the horizontal guide centers on B C and the vertical guide centers on B H. Holding the Frame with the right hand, with the left move the end of the Stick until its ruling edge strikes A. Then a line drawn along said ruling edge will trisect the angle.

The above method will trisect equally well an angle of 180° or 360°, or any intermediate, taking care to place the Frame correctly. A ready and fairly accurate practical check of this method can be made without the instrument by means of the edge of a piece of cardboard, by marking off from one end a distance twice as great as A B. Move the point marking this distance along B C while the end is moved up or down B H until the edge strikes A, when a line drawn along the edge trisects the angle.

To make the instrument applicable to a very small angle, the slot in the horizontal guide must extend slightly beyond the vertical guide, as in that case the stick will be almost vertical. In no case of course can the stick vary more than 30° from the vertical.

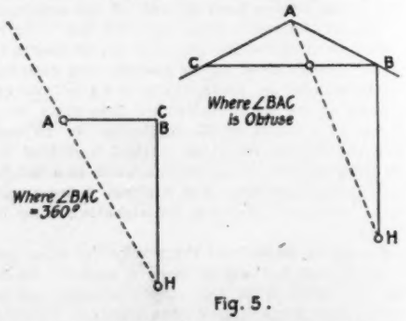


Fig. 5.

Fig. 5. Application of Angle-Trisector.

The principle here shown may be applied, with little change, to construct a linkage which will constantly trisect a variable angle. For example, if in a mechanism of any sort the arms C A and B A (Fig. 5) pinned together at A, have such a motion that the angle C A B constantly varies, then the device may be so arranged that the stick A H always trisects angle C A B. The requisite construction for this purpose is simple and needs no further explanation.

It is believed that this device is original: indeed the writer has not seen mentioned elsewhere the fact that H E equals 2 A B. Any merit or interest it may possess is submitted to the engineering profession generally.

*Contracting Manager, American Bridge Co. of New York, 42 Broadway, New York City.

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Engineering News hardly needs to tell its readers that the year just closed has witnessed the most abounding prosperity that the United States has ever seen, and that the engineering profession, taken as a whole, has shared to the full in that prosperity. This does not mean, of course, that engineers as a class have grown wealthy; for wealth, as measured by present-day standards, at any rate, does not fall to men in return for professional labors, at least in the engineering profession. It does mean that the working engineer in every rank of the profession has nowhere had to remain idle because of lack of demand for his services, and that the scale of payment for these services has been lifted by the law of supply and demand to a better level, probably, than has ever before been reached.

As for that very large section of the engineering profession which is engaged in commercial rather than professional work, we are glad to record that the year just closed has been prolific of business, and profitable business, for the contractor and the manufacturer in nearly every line of work.

The outlook for the coming year could scarcely be brighter. Mills and factories of every sort are being worked to their full capacity to supply orders. Mines are breaking all records in their output of metals, which are sold at high prices. The farms of the United States produced in 1905 crops of a total value of six billion dollars, eclipsing all previous records and furnishing a solid and stable foundation for prosperity in all classes of commercial enterprise.

People have made money in 1905, and a large proportion of this money, in excess of the necessities for current consumption, is available for investment in new enterprises. It is estimated that the mines of the United States will pay 150 million dollars to their owners in dividends as a result of their production in 1905. The payments of American railway companies to their stock and bond holders are likely to exceed 700 million dollars. These figures are sufficiently indicative of the vast river of wealth which resulted from successful productive enterprise in the year just closed and to which we must look for the capital to supply the demands of our rapidly growing industries, in manufactures, mining and transportation, and for the extension of public services in our cities.

It is a great pleasure to be able to record so satisfactory a result for the year just closed and so favorable a prospect for the year just beginning. Engineering News extends to its readers and patrons its hearty congratulation on the prosperous record of engineering during the past year, and especially on the bright outlook for the future.

We have before us an advance bulletin of the U. S. Geological Survey describing experiments on the smelting of magnetic iron ore sand by electricity, made at the Lewis & Clark Exposition last summer, under direction of the Survey. At the head of the bulletin appears the following statement:

Dr. David T. Day, of the United States Geological Survey, makes the noteworthy statement that conditions for the production of steel by electricity are fully as good in Oregon as they are in Germany, where pig iron has been obtained in similar electric furnaces at slightly lower cost than in ordinary blast-furnace practice.

The average reader will certainly take this as an authoritative approval of the electric iron smelting process by a high official of the Survey; but a critical study of the experiments themselves, as reported in the bulletin, does not put by any means so favorable a view on the matter.

Briefly summed up, it appears that an electric furnace was built large enough to contain 1,000 to 1,500 lbs. of mixed ore, coke and flux and the mixture was smelted by the heat produced by an electric current, the smelting requiring 1 to 5 hours. Later a second, slightly larger furnace was built. These furnaces produced from 100 to 500 lbs. of metal at a run. It is called steel, but its quality and composition is not definitely stated, save to the effect that it had many small blow holes, and on one day its analysis showed it to be practically pig iron.

The most interesting figures of the test, of course, are those which show the relation between the steel produced and the electric energy absorbed. The steel produced per horse-power day (of 24 hours) ranged all the way from 2 lbs. to nearly 24 lbs. in one test, which latter figure was so far in excess of the results obtained on any other day that its reliability is very doubtful. The best record on other days was about 15 lbs. per horse-power day, which would be equivalent to the production of a long ton of pig iron in about 150 horse-power days. This result agrees fairly well with the figures set forth in Engineering News four years ago as to the ultimate possibilities of electric iron smelting. If anyone can spell out commercial success anywhere on such a basis of operations, he is endowed with a large amount of courage.

Further comment on these experiments we reserve until the full report upon them is available; but from present indications we judge Congress displayed sound discretion when it recently refused any further appropriations for Geological Survey experiments in producing iron from the black sands of Oregon.

A possible extension of the use of rock crushing and grinding machinery, coupled with a possible important new source of fertilizer, is suggested elsewhere in this issue. The suggestion is based on studies made by Dr. Allerton S. Cushman, of the Office of Public Roads, U. S. Department of Agriculture. The proposition involves the fine grinding of potash-bearing feldspathic rocks, together with either limestone or gypsum, and the possible addition of ammonium salts. It is hoped that by this means the potash in feldspathic rock might be made sufficiently available, and at a low enough cost, to compete with present trade fertilizers. The subject is still in an early, tentative stage, but seems worthy of the attention of manufacturers of grinding and crushing machinery, fertilizer producers and agriculturalists. If the owners of stony farms in New England and elsewhere could kill two birds with every stone on their holdings (that is, get rid of the stone and at the same time provide themselves with fertilizers) it would be a boon for them indeed. Of course the proposition involves no such general possibilities, at least in its present or probable future state, but if it did the abandoned farm problem would be quickly and happily solved. It is conceivable, however, that in some sections no inconsiderable quantities of field stone may be thus utilized at some future day.

A more likely means of getting rid of field stone to advantage, and that without waiting for further developments in either science or industrial art, is the establishment of local stone crushing plants to provide broken stone for road construction and for concrete buildings. Although the field stones of many localities do not afford ideal material for macadam, yet they are often passably serviceable for that purpose, while most of them could be so crushed as to make concrete good enough for all farm purposes. Few farmers are good stone masons, but almost any farmer or farm hand could train himself or be trained to mix concrete, set forms, and build concrete walls. With the increasing price of lumber, concrete may well be substituted for it in many parts of farm buildings, having the great advantage of long life and low maintenance and repair cost. Woven and other forms of wire have largely displaced stone walls for fencing, thus cutting off one of the former chief means of getting rid of field stone to possible advantage. In some cases it might be feasible for farmers to use concrete fence posts, in place of wood. It should be borne in mind that the possibilities of economically using broken stone on the farm, for any and all purposes, will depend very largely upon the ability of the individual farmer to make use of the time not available for more strictly agricultural work; and, of course, upon his resourcefulness and ingenuity as well. The likelihood of his taking time, and having the inclination and the technical or semi-technical knowledge for undertaking such work, will be increased with the growth of well-planned and patronized courses in agricultural engineering at the state and private institutions where agriculture is taught; but much can be accomplished without awaiting for development in this latter direction, which, considering the whole farming population of the country, is bound to be slow.

The latest bulletin of the United States Board on Geographic Names contains one order authorizing a change of name which deserves a wider publicity. We quote it in full as follows:

BEAVER; brook tributary from north to Souhegan River, Hillsboro County, N. H. (Not Quohquinapassakessamanagnog, Quohquinapassakessananagnog, Quohquinapassakessanannaquog, nor Quoh-quinna-passakessa-na-nag-nog.)

A change from any of the Quoh-what-do-you-call-thems to Beaver appears entirely justifiable. An aboriginal name of such a length is out of place anywhere, save possibly on an extra long Pullman car.

One hundred and sixty million dollars for an immense new water supply and not a cent for a systematic crusade against scores of millions of gallons of water waste! Such is the action and the inaction of the municipal authorities of New York city. The neglect of waste curtailment is almost as deserving of condemnation as are the steps to provide a new supply deserving of commendation.

As many of our readers know, Mr. John R. Freeman, in 1900, the Merchants' Association Water Supply Committee, about the same time, and the Burr-Hering-Freeman Commission, late in 1904, each and all reported that immense quantities of water were being wasted in New York and that a well planned and executed attempt to reduce the waste ought to be made at once. Waste curtailment was not suggested as a substitute for an additional supply, but as a possible means of averting the water famine that may come to New York in any dry year during the long period that must elapse before a new supply can be made available. Systematic studies of water waste were undertaken, while Mr. N. S. Hill, Jr., was at the head of the New York water department, and were made a part of the investigations of the Burr-Hering-Freeman Commission. The use of the pitometer in Manhattan

and Brooklyn boroughs confirmed many of the general conclusions of earlier date regarding the large waste of water and pointed clearly to the continuation of such water waste studies by districts, to an overhauling of street mains and valves, to the extension of the meter service, and to the adoption of stringent measures against the evasion of both meter and schedule charges by consumers large and small. Very likely minor measures against water waste and stealing have been added to those already in force, and we suppose the old and new efforts to curtail waste and to get value received for water supplied have been prosecuted with more or less vigor. But nothing commensurate with the gravity of the situation has been done, nor, what is worse, seems likely to be done in the near future.

New York needs a well organized water waste prevention bureau, manned with a capable and experienced engineering and clerical force and equipped with the most modern apparatus. The latter would include, first of all, and in so far as it is still lacking, an adequate number of properly located valves to divide the city into water waste districts, large and small; next, permanent meters to record the flow to each of the larger districts; then portable meters for special investigations of both large and small districts; and finally street and house inspectors equipped with waterphones or other devices for locating small leaks. Of course such a bureau as this should be supplemented by and work in harmony with the regular meter department, and that department should at once install meters wherever waste is found and persisted in on unmetered services.

Whether or not meters should be applied as rapidly as possible to all water services, raises too many and perhaps too local questions for present discussion, but such a practice is directly in line with the ideas of a rapidly increasing number of water-works engineers and superintendents, and, moreover, it is being adopted by many cities and towns. Meters are by all odds the best detectors and repressors of waste on consumers' premises, and aid greatly in the discovery and location of underground waste. In addition, and of great importance, meters afford the only equitable means of apportioning the cost of a public water supply between individual consumers. When the proposed Catskill supply has been introduced, the works for the supply and distribution of water to Greater New York will represent an investment in excess of a quarter billion of dollars, and the daily supply of water for the greater city will be something like a billion gallons. Shall works of such value and of so great importance to the property of the city and the comfort, health and life of five or six million people be administered without the use of every known and approved method to prevent waste and inefficiency? It is to be hoped not. The best evidence to the contrary would be the immediate adoption and encouragement of wise measures to locate and stop all gross water waste and to collect from every water consumer his just proportion of the cost of a water service which is mounting so rapidly in cost and quantity.

We desire to call the especial attention of our readers and contributors to the particularly valuable character of two articles in the present issue which treat of the design of two classes of engineering structures. It is articles of this sort, which treat directly problems in *design*, that we believe to be the most valuable sort of engineering literature. Descriptions of particular pieces of engineering work were well enough when the amount of engineering work done was trifling compared with the present day; but nowadays what engineer has time to read a description of a completed engineering work unless it contains some features bearing directly on problems which he himself has to solve?

Of course, there are many pieces of engineering work which, because of their novelty, or their magnitude, or for other reasons, are well worth description, and we shall in the future, as in the past, publish many articles describing such works. Nevertheless, our opinion is that the most valuable sort of engineering literature is that which discusses directly the problems of design which the working engineer has to solve; and contributions of this class are always sure of a welcome at the office of Engineering News.

A NEW YEAR'S SURVEY OF MUNICIPAL CONDITIONS.

The municipal outlook for the new year is unusually bright. The general prosperity of the country warrants the continuation of municipal improvements on a large scale. Nearly all the engineering and other technical problems pertaining to municipal public works have been so far solved in their general features as to leave relatively little to be done, save to apply and adapt existing knowledge and practice to special conditions of time and place. Most encouraging of all, the recent civic awakening that has shown itself in so many ways of late and was so notable a feature of the last November election bids fair to be permanent and to manifest itself by a wider and more intelligent interest in municipal affairs on the part of citizens, and, as a consequence, by a great improvement in the character and capability of municipal officers and administration alike. But we must not let a broad and highly generalized view of municipal conditions so fill us with complacency as to blind us to the serious dangers that still beset municipal progress. Chief among these are (1) the utter lack of experience of the vast majority of the newly elected and appointed municipal servants raised to office each year; (2) a failure to recognize the fact that there is quite as much need for money and brains in the operation and maintenance of city works as in their design and construction.

It is interesting to note how generally the American municipality, down to small towns and villages, is now provided with facilities which only a few years ago were to be found only in large communities, or else had not even come into use anywhere. Complete statistics to illustrate this point have never been gathered, and no summary to date is available; but we know that early in 1902 (see "The Municipal Year Book" for 1902) nearly all places in the United States with populations of 3,000 and upward had water-works, electric lights and telephones; that more than two-thirds of them had sewers for the removal of household wastes, and nearly two-thirds both gas works and street railway facilities. Only 28 of 1,524 cities and towns were then without public lighting by either electricity or gas, and only 46 of the same 1,524 places lacked water-works for domestic supply and fire protection. Of municipalities having as many as 5,000 people by the 1900 census only six were without water-works early in 1902, and one of those had a water service for fire protection only.

The foregoing figures are inadequate, because they do not show the large number of places under 3,000 population that have some or all of the services named. In this respect they are doubtless most deficient as regards water-works. At all events, so far back as the close of 1896 (see "The Manual of American Water-Works" for 1897), there were in the United States 3,480 cities and towns which were known to have domestic service and fire protection from water-works plants, and about 500 additional towns with water service unclassified, or for either domestic or fire purposes alone. It will be seen, therefore, that as long ago as 1896 there must have been some 50% more water-works in places of less than 3,000 people than in places of more than that number. To-day the number of water-works in towns of less than 3,000 inhabitants is more than double the number in municipalities of larger size.

Of the six classes of service named, telephones, street railways and gas works are practically all owned privately. Municipal initiative has had but little to do with their introduction and has done far less than it should to ensure good service from the private owners. A considerable proportion of the electric light plants, a majority of the water-works and practically all of the sewerage systems are municipally owned.

Outside the six industries named, American municipalities have done a great deal in the way of providing parks and of meeting such obvious municipal demands as improved streets and fire protection. Less generally accepted municipal functions, such as public bath houses, water closets, gymnasiums, markets, wharves, ferries and cemeteries, are exercised in varying degrees but for the most part American cities are far behind British municipalities in these matters. Public baths and playgrounds are growing in favor and frequency, and are destined to become a well-recognized feature of the modern city. Both will be considered essential adjuncts of public schools in crowded quarters before many years pass by.

Central heating plants are becoming common—generally to utilize the exhaust steam from electric light and power stations. Although far less numerous and well known, central refrigerating plants exist in a number of cities. Very likely they will be a feature of many cities of the future.

Besides the activities mentioned, our municipalities do an immense amount of street construction and maintenance, collect and dispose of more or less garbage and other refuse and look after the public health, besides performing many other duties which do not concern us.

The work done or sanctioned by the American municipality in behalf of its citizens is certainly large and various; but does it rank as high in quality as in quantity and variety? Unfortunately, not. But this disparity, we hasten to say, is due to other causes than a lack of knowledge or of capable men to put knowledge into effect. It results from a failure to utilize the measures and men that are available. This, in turn, is due very largely to forces which are frequently, if not generally, able to put men into city legislative chambers and mayor's chairs because of their known devotedness to party or private rather than to public ends. Such men have little knowledge of the duties and little regard for the responsibilities which the public has a right to expect of them, and are not likely to place in appointive offices men more capable or conscientious than themselves. The increasing demands of the public for municipal services of many kinds are met, but with too little regard for either efficiency or economy, the public for the most part being unable to judge of either. It often happens, however, that very creditable public works are provided, but that, as already mentioned, they are never properly operated, being turned over to some inexperienced political appointee.

It would be tedious, if not useless, to dwell on these drawbacks to municipal enterprise and administration. Having called attention to them and to their serious nature, we may pass on to a brief consideration of the present status and tendency of some branches of the municipal service, particularly those more closely related to engineering and sanitation.

Water-works being one of the oldest and most common municipal enterprises of an engineering nature, it may properly be discussed first. In design and construction water-works practice now follows well accepted lines. The objects to be attained are purity, volume and pressure—all as uniform and as dependable as possible. For purity, reliance is being placed more and more upon filtration rather than upon so-called naturally pure sources; that is, where surface supplies are used, as they are for nearly all large and many small cities. An adequate volume at reasonable cost is largely dependent upon the suppression of waste, which can best be effected by the use of meters. The curtailment of waste is also a great aid in maintaining an adequate pressure on existing works.

The recent notable advances in water-works practice are improvements in the construction and operation of filtration plants; increased efficiency in pumping machinery and in its adaptability to various conditions of service; the rapid extension of the use of meters; the adoption of standard specifications for cast-iron pipe and specials and of standard hose and hydrant threads; and improvements in pipe-tapping and cutting machines.

The greatest menace to the integrity and reliability of the water service to-day is electrolysis. The cause and the remedy are well known, but the difficulty lies in forcing the street railway companies to keep their return currents from the water mains. Water authorities must never relax their watch for dangerous electrolytic conditions, and if unable themselves to make the necessary electrical surveys they should employ a capable man to do so at frequent intervals. But effort must not stop here. Pressure must constantly be brought to bear on the traction companies to get them to return their electric currents to the power house. No available means to place the responsibility for damages from electrolysis upon trolley companies should be spared.

Of water purification it may be noted, in addition to what has been said, that both slow sand and mechanical filtration have now been developed to such a degree of sanitary and economic efficiency that there is no longer an excuse for supplying anything but clear, colorless, tasteless and pathogenic-germ-free water to any municipality, large or small. The choice between slow sand and mechanical filtration depends chiefly upon purely local conditions, and may safely be left to the engineer, chemist and bacteriologist. In round numbers, $10 a million gallons, or 1 ct. per 1,000 gallons, will pay the capital and operating charges of water purification. This is a small premium, indeed, for protection against typhoid fever, to say nothing of improvements in the physical character of water. The American city of the future, like the British and German city of to-day, will rarely tolerate unfiltered water when the water is drawn from streams, ponds or lakes.

It is natural to turn from water-works to sewerage, but here comment on sewage disposal will be most pertinent. It may be stated, however, that the rapid extension of sewerage systems, both in number of cities supplied and in areas served within each city, is highly desirable. Aside from the commonly accepted reasons of convenience and hygiene, which will not be reviewed, there may be noted the following reasons for sewer extension: (1) The extension of sewers is a great aid, and sometimes almost a condition, to getting rid of polluted wells, both by lessening the pollution from privies and cesspools and by hastening the introduction of water into houses. (2) Privies and cesspools, through the agency of flies and mosquitos, are great factors in spreading typhoid fever and malaria.

In sewage disposal, where some means of treatment is required, there is more confusion just now than in any other branch of municipal engineering. This is largely due to misconception of the general problem, eagerness to adopt some of the newer methods before their nature and adaptability to local conditions are thoroughly understood, and a general failure to put the management of sewage works in the hands of technically trained men. The leading American sanitary engineers may be relied upon to choose a method of treatment and to design and install works well adopted to local needs, but throughout the country men practically without knowledge of either old or new methods are being called upon by still less informed city councilmen and committees to design sewage works, and the resulting plants are being turned over for operation to men who never before saw or heard of settling or septic tanks, contact beds or intermittent filters. Under such conditions it is not strange that sewage treatment in America is on a far less satisfactory basis than water purification. But we hasten to add that the sewage problem is newer, more complex in some respects, and in all respects less vital than the water problem, so allowances should be made accordingly. We also take pleasure in stating that a fairly large portion of the municipalities now having sewage works in use or under construction have entrusted their design to experienced engineers, and that a few, though only a very few, cities and towns employ well trained men to operate them.

No process of sewage treatment has yet been, or seems likely to be, proven superior to all others. Each local problem must be solved in accordance with local conditions, whereupon the choice may lie among a number of processes.

The average uninformed American city councilman or sewer commissioner generally places far too much confidence in the septic tank, which effects only a partial purification and does not wholly solve the sludge problem. Many engineers make exactly the same mistake. Where some form of filter bed is deemed necessary, intermittent filters are generally the first choice, provided sufficient areas of cheap, coarse-grained sand are available. Next in favor to intermittent filters stand contact beds. The percolating filters which are becoming so popular in Great Britain have been scarcely used as yet in America, although they are to be installed on a large scale at Columbus, O.

The mention of Columbus suggests the desirability of repeating elsewhere such well-directed, large-scale studies of sewage treatment as were there made, and as have been made so many times in Great Britain, before attempting to design sewage works involving relatively untried methods of treatment.

It may be well to note before passing from sewage treatment to garbage disposal that the chief object of sewage treatment is to prevent nuisance due to offensive sights or smells and not to produce an effluent so germ-free that it may safely be discharged into drinking water or over an oyster bed. Shellfish beds in close proximity to sewer outfalls, whether or not the sewage be purified, should not be drawn upon for food. Only in rare cases, if at all, should reliance be placed on sewage purification for the protection of public water supplies; instead, the water itself, or both the water and sewage, should be purified.

In considering the disposal of garbage and other city refuse, we wish to emphasize the fact that, as compared with many other municipal services, this is a matter of public convenience rather than one that deeply or widely affects the public health. Nevertheless, the proper and economical disposal of garbage, ashes and the like is an important municipal function, and one that has been poorly exercised or shamefully neglected by most cities and towns. This failure is largely due to not regarding refuse disposal as an engineering problem. As a result the majority of the hundred or so garbage furnaces thus far built have been abandoned for one structural defect or another, or because of excessive cost of operation. Reduction plants for the extraction of grease from garbage and the production of fertilizing material from the residue or tankage are, with the recent exception of the one at Cleveland, O., all operated under contract, and, as a rule, the contracts have been so framed, or the contractors have been so poorly supervised, that it is difficult to judge whether or no the work is being done at fair prices. Nearly all the largest cities of the United States have their garbage treated by reduction plants. There is no reason why these plants should not be so located and operated as to produce no nuisance of moment. As to their economy, as compared with cremation, we may know more when the figures for the first year of municipal operation at the Cleveland plant are available.

A large part of the municipal expenditure of the country goes for street paving. In many of our cities the results are not commensurate with the expense, if one judges by the condition of the pavements after a few years of use. But here defects are due largely to niggardly appropriations and bad administration rather than to poor materials and bad construction. Until within a comparatively few years American pavements were quite generally deficient because they lacked proper foundations. The defect has been recognized and overcome in most progressive communities. It is now an axiom that the foundation of a pavement should be considered as a reasonably permanent support for the stone, brick, wood, asphalt or other wearing surface. As to which of these surfaces should be laid there is plenty of latitude for choice to meet local conditions. Wood block pavements years ago received an undeserved bad name through the use of wood not treated with a preservative, and also on account of the extensive use of round blocks on end in Chicago and other Western cities. The results are too well known to require description. Within the past few years rectangular blocks, well treated with preservatives, have been rapidly introduced in many cities, and have been giving much satisfaction. During about the same period an improved tar macadam, or bitulithic pavement, has been extensively laid, and has met with favor. Where freight rates from paving brick centers permit, brick seems to hold its own as a paving material. Sheet asphalt continues to stand high in popular esteem and in engineering merit, but attempts to maintain an asphalt monopoly and various business complications have checked the natural extension of the use of this material.

Pavements of all classes are ruined almost as rapidly as laid by being continually torn up to lay or gain access to underground pipes and wires. Much of the damage could be prevented by a proper system of supervision on the part of the street authorities, but in the larger cities the evil will never be remedied until pipes and wires are placed in subways and access to them made possible without disturbing the street surface. Such a course would have many other advantages, one of which would be the ready discovery and repair of leaks in gas and water mains, while another would be the greater ease with which the streets could be kept clean.

Street cleaning has been greatly improved in a number of American cities since the late Colonel Waring showed what could be effected in New York by a well-organized department, but the standard set by him is not often attained. Street sprinkling is more or less essential in warm weather, but under ideal conditions there would be so little dust in the streets that watering would be practiced chiefly to cool and preserve the pavements; in other words, the streets should be so clean that there would be little dust to be laid. This would involve, first, a non-dust-generating pavement, or the nearest possible approach to it, and, second, one that could be cleansed by washing or possibly by some dustless vacuum cleaner.

Fire protection might be greatly strengthened at many points, notably by providing larger and better arranged mains, more hydrants and better fire-alarm systems. Some of our cities are very well served in these respects, but relatively few of them do all they profitably might in the way of frequent pressure tests, or, better yet, permanent pressure-recording gages well distributed throughout their area. Such measures are valuable as indicating needed readjustments in distribution systems or reinforcements of the volume or pressure of the water supply. The use of automatic sprinklers in stores, factories, warehouses and specially hazardous portions of public buildings might well be extended. One of the most helpful of all fire-prevention measures is a well-enforced, stringent building ordinance, both as regards construction and maintenance. In a closely built city absolutely fireproof buildings may be impossible, or at least impracticable, but fire-resisting construction is wholly practicable and has prevented many a serious conflagration. Unfortunately, the real estate and building interests too often resist well-conceived efforts which if realized would be for their own permanent good and oppose both the adoption and enforcement of desirable building ordinances.

Much might be said regarding health protective work, but space forbids more than touching upon the subject. Aside from a few of the more progressive cities and towns, the health departments of American municipalities are poorly manned and very inadequately supplied with apparatus and money for fighting disease. The milk supply should be recognized as a most important factor in the spread of typhoid fever, scarlet fever and diphtheria, and as even more important in its relation to the general health of a community. Hitherto the public supervision of the milk supply has concerned itself chiefly with adulteration. It should now turn relentlessly against dirty milk. Isolation of persons suffering from communicable diseases should be more generally and strictly enforced. Disinfection after

the termination of such diseases should be more efficiently performed. Medical inspection of the schools should be established. Adequate ventilation of school and other public buildings should be secured. Light and air should be let into tenements, good plumbing fixtures should be provided and overcrowding should be stopped. A campaign against tuberculosis or consumption, largely educative, and addressed to the well-to-do no less than the poor, should be inaugurated and vigorously prosecuted wherever not already under way. The possibilities of reducing the ravages of pneumonia as well should be given most serious attention. These two diseases are singled out for mention because together they cause 20% to 25% or more of the total mortality of our cities. Consumption is already yielding to the efforts directed against it, but pneumonia, which is also communicable, seems to be increasing rather than decreasing.

No space is left to discuss one of the most commanding questions of the day—namely, municipal ownership. The subject is so important and so complex as to need separate attention. To mention the municipal ownership controversy suggests another topic on which an intelligent discussion of the former largely hinges, and which must also be passed by—needed improvements in municipal accounting. Without such improvements we shall continue to be in the dark as to the economic efficiency of municipal undertakings in general, regardless of their ownership.

In conclusion, we would emphasize the statements made in our opening paragraph—that the municipal outlook for the new year is unusually bright, but that the brightness must not be allowed to blind us to the dangers in the path of municipal progress.

LETTERS TO THE EDITOR.

The Proper Heat for Rivets.

Sir: I think that in actual practice the maximum heat for field rivets is nearer a lemon color heat by daylight than that called for by Mr. Henning in Engineering News of Nov. 16th.

Very truly,
J. W. Carrier.

412 W. Pleasant St., Corry, Pa., Dec. 23, 1905.

Concerning the Detection of Burned Rivets.

Sir: At p. 671 of your issue of Dec. 21, 1905, Mr. Edward Godfrey reads into my statements what is not contained in them. I referred solely to pits in rivets *while hot*, produced by burning or melting. Pits are most rarely produced during driving by flakes of rust supposedly left in the cups of the sets. The inner surface of the sets is almost invariably polished. The rust broken off by each hammer blow immediately jumps out of the cups of the sets, unless the rivet is driven upside down, which is indeed a rare occurrence. The cup in the "dolly" (lower cup) may catch some rust, but the depression made by this is radically different from a "pit." If Mr. Godfrey will observe closely he will see that a newly driven head is rarely pitted. The pitting referred to is seen before driving and is removed by driving.

Yours truly,
Gus. C. Henning.

150 Nassau St., New York, Dec. 22, 1905.

A Specimen of Mathematical Reasoning in a Circle.

Sir: I beg to submit herewith a very interesting example of mathematical juggling, in which the author attempts to prove something by a method that is primarily dependent upon the very fact which he is setting out to prove. I ran across it in a very practical work on the Calculus, in which the author attempts to prove that the length of the circumference of a circle is $2\pi R$. His proof is substantially as follows:

Equation for circle is $x^2 + y^2 = R^2$

differentiating $\frac{dy}{dx} = -\frac{x}{y}$

length of a curve is $S = \int \sqrt{\left[1 + \left(\frac{dy}{dx}\right)^2\right]}\,dx$

or $S = \int \sqrt{\left(1 + \frac{x^2}{y^2}\right)}\,dx$

$$S = \int \frac{R\,dx}{\sqrt{1 - x^2}}$$

which for whole circle is $S = 4\int_0^R \frac{R\,dx}{\sqrt{R^2 - x^2}}$

$$S = 4R\left[\sin^{-1}\left(\frac{x}{R}\right)\right]_0^R$$

$$S = 4\pi\frac{R}{2} = 2\pi R$$

It will be noticed that the last step is based on this fact: that the angle whose sine is unity is $\frac{\pi}{2}$ in circular measure and since the unit angle of circular measure is an angle whose arc equals its radius he thereby assumes that the arc of a quadrant is $\frac{\pi}{2}$ times its radius, which is virtually what he set about to prove.

Respectfully, John D. Adams.

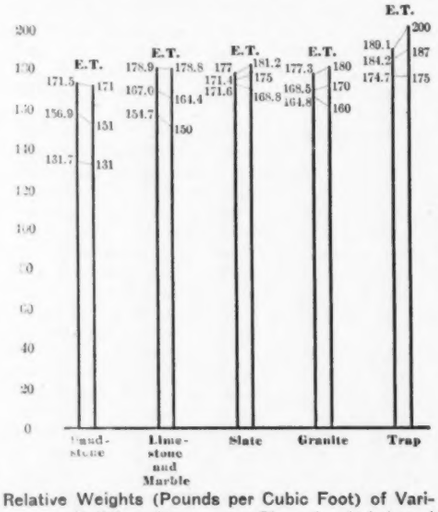
Phoenix, Ariz., Nov. 29, 1905.

Weights of Various Building Stones, as Given by Eckel and Trautwine.

Sir: In Engineering News of Sept. 7, 1905, under the title, "Specific Gravity and Weight of Building Stones," etc., Mr. Edwin C. Eckel, of the U. S. Geological Survey, gives a table of weights, per cubic foot, of building stones, based upon data obtained from various sources.

In this connection, Mr. Eckel remarks: "The tables . . . which are given in engineering pocket-books . . . are largely based upon English data of questionable accuracy and of very ancient date."

The accompanying diagram shows the maximum, average and minimum weights, per cubic foot (marked



Relative Weights (Pounds per Cubic Foot) of Various Building Stones, as Given by Eckel and Trautwine.

(E = Eckel. T = Trautwine.)

"E"), given by Mr. Eckel for building stones, as compared with those (marked "T") given in our "Civil Engineer's Pocket Book," as now published.

These are the data given in our fourth edition (1876) and they differ but slightly from those in our first edition (1872). Our figures (somewhat higher than Mr. Eckel's) for trap are specified as applying to a "compact" article.

Yours truly,
John C. Trautwine, Jr.

257 S. Fourth St., Philadelphia, Pa., Dec. 19, 1905.

A Suggestion for Roof Pitch Computations.

Sir: The writer offers the following two time-saving suggestions in regard to ¼ and ⅓ pitches, when dealing with those Tables of Squares which contain the logarithms, as well as the squares, of the dimensions.

In a roof of ¼ pitch the rise is one-fourth of the total span. Fig. 1 shows the half-span and might be termed the elementary triangle for ¼ pitch. Now the usual

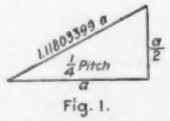


Fig. 1.

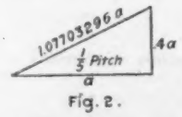


Fig. 2.

method of finding the length of the hypotenuse, or rafter, is to look up the square of a, to this add ¼ the square of a, and in the table of squares to look up the length corresponding to this sum of the squares. Now the logarithm of 1.118 is .04844. By neglecting the other figures, the error in the length of the hypotenuse is but .0408-in. (less than 1-16-in.) when a = 100 ft. Now the length of the rafter is found by adding .04844 to log a, and looking up the number corresponding to the log of the sum. This number .04844 is easy to identify with ¼ pitch, since it is made up of fours and a multiple of 4.

Fig. 2 shows the elementary triangle for ⅓ pitch. The log of the hypotenuse may be taken as .03222 with an error of .0287-in. (less than 1-32-in.) when a = 100 ft. The connection of this logarithm with ⅓ pitch fixes itself upon the mind in that the sum of the first two digits is 5.

The writer has had no trouble in keeping the two pitches distinct. The use of these logs involves but three operations against the four operations necessitated by using the squares. The writer has found most utility in these logs when working back from a given hypotenuse to the span; in which case, of course, these constant logs are subtracted from the log of the hypotenuse.

Yours respectfully,
C. L. Bogert.

McClintic-Marshall Construction Co., Rankin, Pa., Dec. 7, 1905.

Notes and Queries.

E. B. H., of Seattle, desires information regarding the most up-to-date method of filing such office maps and plans as accumulate in the course of the practice of a civil engineer.

NEEDED IMPROVEMENTS IN THE TRANSPORTATION OF PERISHABLE FRUITS: A REFRIGERATION PROBLEM.

The transportation of perishable fruits involves some problems of great interest to the engineer; problems, too, upon which the future of the fruit growing industry largely depends. These problems, which relate chiefly to refrigeration, were discussed recently by Mr. G. H. Powell, Pomologist in Charge of Fruit Transportation and Storage, U. S. Department of Agriculture, in a paper read before the American Society of Refrigerating Engineers.

Fruit raising is a great industry in the United States, and is rapidly increasing in importance in all sections of the country. This growth is bound to continue, since fruit is becoming a staple food rather than a luxury, and since our orchards are called upon to supply large quantities of fruit to foreign markets.

Although orchards are being planted in every State of the Union fruit growing for the general market is largely concentrated in areas specially favored by conditions of soil or climate.

To utilize local advantages to the utmost, in supplying both American and foreign markets, reasonably cheap long-distance transportation of fruit, without deterioration, is essential. On this subject Mr. Powell says:

The future development of the American fruit industry depends on the ability of the producer to lay down his crops quickly and in sound conditions in distant markets both domestic and foreign. Efficient transportation is the keystone which must determine the stability of the industry. So-called overproduction is the result of an inadequate system of distributing a crop widely and safely. Inadequate transportation means temporary gluts followed by barren markets. Under a proper system of distribution there is little danger of the overproduction of most kinds of American fruits, if a high standard of grading and of quality is maintained.

One of the principal difficulties that the fruit grower or shipper has to face in extending the fruit trade is the limitation in the distribution of fruit on account of the ripening and the development of decay that may occur in refrigerator cars. In ordinary practice, fruit is loaded in cars in a hot condition. It requires several days after the fruit is loaded to reduce the temperature of the fruit to a degree of cold that retards the ripening and the decays. During the first few days the car, especially in the top, is warm. The ripening springs forward during that time, and as the atmosphere is moist, the rots may begin to grow vigorously. These are fundamental difficulties in the present method of handling fruits for transportation. They have a far-reaching influence on the development of the fruit trade. They limit the distribution of the perishable fruits, thereby preventing the greatest development of distant domestic and foreign markets. They also make it necessary to pick the summer fruits prematurely to protect against the ripening in transit, thereby placing enormous quantities of insipid, flavorless peaches, plums, and other fruits before the consumer.

Mr. Powell cites several specific examples of important fruit crops which are limited in the markets they can reach by the defects in present

methods of handling, even with the most perfect transportation (including in this term the refrigerator car service). He instances the Georgia peach, the California peach, and the California citrus fruits, describing the conditions of packing and transportation, and the results. As he says, examples might be cited in almost indefinite number; we quote his third example as typical:

Citrus Fruit Industry.—The losses from decay in transit in the orange and lemon from California amount to about one-half million dollars annually. The orange is wrapped and is packed tightly in boxes that weigh 72 lbs. when full. The packages are stacked on end in the car, usually two tiers high. After the first of March the fruit may range from 60° to 90° F. in temperature when loaded. The temperature of the air in the refrigerator car may drop to 40° to 50° in three to ten days, but the fruit in the center of the package remains several degrees warmer for many days. As a result the decay in the fruit in the top tier of packages is greater than in the bottom, often by 10%, and worse in the center of the package in both tiers. We know that the orange can be stored safely for many weeks at 40° temperature if the fruit is stored quickly after picking. The problem that the California citrus-fruit grower wants solved is, how can the fruit be handled so as to insure the safe arrival of all parts of a cargo in the most distant domestic and foreign markets. California now produces 30,000 carloads of citrus fruits. The problem will need to be solved in the near future to prevent temporary domestic gluts by the opening of more distant markets.

The conditions of transit are not the sole cause of the deterioration of fruit before reaching its market; on the contrary, the apple and the orange suffer perhaps larger loss from rough treatment in picking and packing. Bruised fruit is likely to develop losses even under the most favorable conditions in transit. The methods of handling the fruit crop need to be reformed. But the improvement most directly needed, or at least that which appeals most directly to the engineer, is the improvement of transportation. Mr. Powell specifies the possible paths of this improvement very succinctly:

An economical, practical method to reduce the temperature of the fruit more quickly after packing than is accomplished by the ordinary refrigerator car is therefore urgently needed. A more uniform distribution of the air in the car is also needed.

Nearly 400 patents have been taken out in the United States with a view to improvement in the refrigerator car service. The patents cover construction, air circulation within the car, ventilation, the capacity and arrangement of ice tanks, mechanical and chemical refrigeration, and various other subjects. There has been an enormous improvement in the efficiency of the refrigerator car since the first patent in 1867. The improvements have usually been attempted by modifying incidental features of existing cars, and those in practical use have been selected with a double view to efficiency in refrigeration and ease of adaptability to the requirements of modern railroading. Complicated mechanism, of which there are innumerable instances in the patents referred to, is apparently impracticable when applied to the modern refrigerator car. Anything that delays the movement of trains or is beyond the skill of the average brakeman to handle is clearly out of place.

I do not care to express an opinion as to the possibility of improving refrigerator cars along the lines mentioned. I would refer those problems to the expert engineers, and I would propound these questions for further consideration:

Refrigerating in Transit Alone.

(1) Is it possible to construct a refrigerator car to be cooled with ice that will refrigerate a load of strawberries or peaches in hot weather quickly enough to check the rots and the ripening of the fruit in the warmest parts of the car?

(2) If not with ice alone, then with ice and salt, with liquid air or by other methods of chemical or mechanical refrigeration, keeping prominently in view the fact that complicated mechanism is of doubtful utility in the handling of the refrigerator car service.

These things have not been fully accomplished by the 400 patents on refrigerator cars. If it is not practical to do so, then we would propound the further query:

Cooling Fruit Before Shipment.

(3) Should a refrigerator car reasonably be expected to accomplish the initial refrigeration of the most perishable fruits in hot weather and to maintain the refrigeration afterwards, or should we ultimately expect the refrigerator car merely to transport safely perishable products that are placed in the car in good condition for transportation? Under present methods of handling fruits the losses originate largely during the period of slow initial refrigeration. In the fresh meat trade this difficulty is obviated by refrigerating the products before shipment and by maintaining a lower temperature in transit by the use of ice and salt. Perishable fruits from Australia to the United Kingdom are likewise refrigerated before shipment. Most of the eastern grown Bartlett pears are refrigerated in warehouses before exporting. Bananas are now being cooled in train loads in transit, and it is proposed to refrigerate the cantaloupes in the semi-arid Imperial valley of Coachella, California, before shipment to the East.

We know that many of the large commercial losses in perishable fruits in transit would be overcome if a practical method could be devised of cooling fruit efficiently and economically before shipment, provided an equal improvement in the methods of handling the fruit in the orchards and packing houses can be brought about. We know that the refrigerator cars in common use when well iced will maintain a uniform temperature of 35° to 40° in a load of fruit indefinitely, that the fruit can be allowed to ripen more fully on the trees if cooled before shipment, that the differences in maturity between the fruit in the top and bottom of the car are largely reduced, and that the fruit arrives with better quality, as the air of the car is dryer and purer during the trip. Therefore I desire to ask the following questions:

(4) Is it practicable to construct warehouses at fruit shipping points, to be operated as a private or a transportation enterprise, at central packing houses or on large fruit ranches for the quick cooling of fruits, the probability being that the warehouses would be used a comparatively short period of the year unless it could be combined with a cold storage and ice-making business?

(5) Is it practicable without interfering with the movement of traffic to refrigerate fruit initially in cars by blowing cold air through the car from a refrigerating machine?

(6) If the fruit could be loaded at a temperature of 35° to 40° could the freight carrying capacity of the car be increased by closer piling and higher loading without endangering the condition of the fruit?

(7) Could the capacity of the ice tanks be reduced, the temperature of the fruit still be maintained and the carrying capacity of the car be further increased under this method of treatment?

(8) Does any method of maintaining a low temperature seem more practical than the use of ice?

These are some of the fundamental problems that the fruit grower has to face in his effort to build up the American fruit industry. They are not problems that can be settled offhand by the grower, the shipper, the car line, the railroad or the engineer. The interests of each are closely interwoven with the interests of the others.

A NEW CONCRETE COVERING FOR TIMBER PILES IN TEREDO-INFESTED WATERS.

The protection of piles used in seacoast structures from the ravages of the teredo and other marine borers has settled down to the application of an armor of some material that cannot be penetrated by the beastly reptiles. Creosoting and other chemical treatments of the wood itself after a time lose their efficacy, being dissolved away by the salt water. A time-honored form of protection consists in threading lengths of vitrified sewer pipe over the top of the pile and filling the annular space with concrete. In much of the San Francisco harbor works a cylindrical wooden tubbing is built around the piles, which in wharf work are placed in clusters of three piles, and the annual space is then filled with concrete. The wooden shell or tubbing is soon eaten away by the teredo, leaving the concrete still in place to protect the pile. In Europe lengths of concrete pipe reinforced with Monier netting have been used in much the same manner as is the tile sewer pipe armoring noted above.

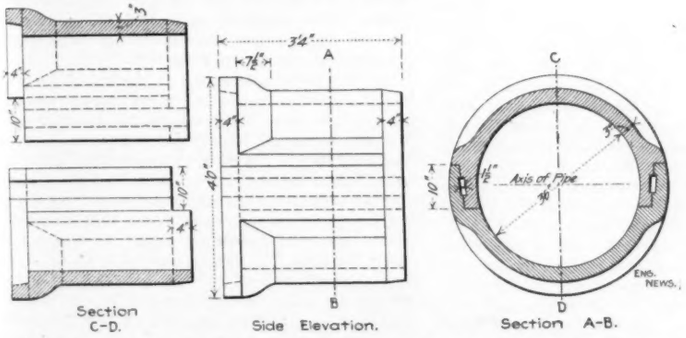


FIG. 1. DETAILS OF LOCK-JOINT CONCRETE PIPE ARMORING FOR TIMBER PILES.

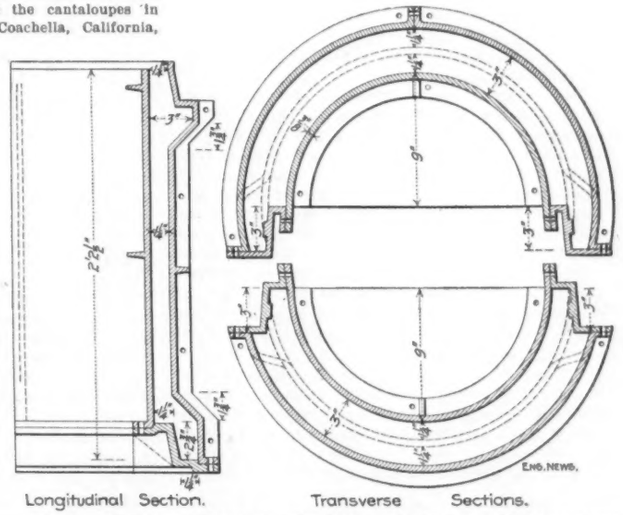


FIG. 2. DETAILS OF MOLD FOR CASTINGLOCK-JOINT CONCRETE PIPE ARMORING FOR PILES.

Two objections have been raised to the forms of armoring mentioned. The first is that the concrete filling adheres closely to the pile and, although it thoroughly protects the pile at first, as soon as any scour lowers the level of the bottom a section of unprotected wood is exposed to danger. The second is that all of the one-piece tile or concrete cylinder armorings have to be threaded over the top of the pile, and therefore have to be applied as soon as the pile is driven and before any of the superstructure framework is in place. To overcome these objections Mr. Philip Aylett, Assoc. M. Am. Soc. C. E., Bridge Engineer of the Seaboard Air Line Ry., has designed the two-piece concrete pipe armoring shown in the accompanying drawings.

The drawings of Fig. 1 show the construction of a length of pipe: a 36-in. pipe is here shown, but there are, of course, smaller diameters. In general form and in its bell-and-spigot joints the pipe resembles ordinary tile sewer pipe. It is molded, however, in two half-rings, which are assembled by scarf joints provided with keyways and secured by wooden keys. As will readily be seen, the two-piece construction permits the pipe to be clasped around the pile at any time after it is driven. The pipe is made of 1 part Portland cement and 3 parts sand mortar, and is sometimes reinforced and sometimes not. For reinforcement practically any form of small mesh netting may be used.

The pipes are molded in place on the work, cast-iron molds of the construction shown by Fig. 2 being used. This particular mold was used for making the 18-in. pipes used in the Seaboard Air Line Ry. bridge across the Manistee River, at Manistee, Fla. The cement and sand

mixture is poured into the molds rather wet and is allowed to set 48 hours before removal.

The idea on which this form of armoring has been designed is that it can be applied to existing as well as to new structures and that, by filling the annual space with sand, an armoring is had which will slip downward and over any part of the pile left exposed by scour. The pipe is manufactured by the Lock Joint Pipe Co., of 346 Broadway, New York City, and we are indebted to the officers of this company for the information from which this description has been prepared.

MUNICIPAL OWNERSHIP AND RAILWAY RATE REGULATION BEFORE THE AMERICAN ECONOMIC ASSOCIATION.

The 18th annual meeting of the American Economic Association was held last week at Johns Hopkins' University, Baltimore, Md. The sessions continued over three days, but the proceedings of chief interest to engineers were the discussion on railway rate regulation on Wednesday afternoon, and that on municipal ownership, on Thursday morning. On each of these questions two speakers, representing diametrically opposing views, occupied half an hour each, and then various prominent economists discussed the papers as presented.

The railway rate regulation session opened with a paper by Prof. Hugo R. Meyer, of the University of Chicago, whose paper followed similar lines to those laid down in his recently published book, which was reviewed in our Engineering Literature Supplement for November, p. 533. Prof. Meyer claims that his studies have shown such inferior results in the case of the State operated railways of other countries, as compared with the railways of the United States, that we should take no steps toward interference by the Government with the railway companies of the United States. His main argument is that the privately managed railways, free from government control, can make rates to suit local conditions, whereas the inevitable tendency of government interference with railway rates is to reduce them to a uniform basis and make them so difficult to change that they cannot be varied to meet local circumstances and changes in conditions.

The argument in favor of railway rate regulation was made by Prof. B. H. Meyer, formerly professor of economics at the University of Wisconsin, and now State Railway Commissioner of Wisconsin. He declared that reliance on competition to protect the interests of the public in dealing with the railways had been proved a failure in every country in which it had been tried. Combinations and "communities of interest" have practically ended the competition between different lines of railway as a factor in fixing rates in the United States. The fine-sounding phrases about the railway rate expressing commercial conditions and being the product of the free interplay of competitive forces, Prof. Meyer said, were empty words and nothing more. As a matter of actual fact, the railway rate is itself the creator, in many cases, of the very commercial conditions it is said to express. No serious defence of the present system, or lack of system, in railway rates is possible. It is mere chaos, the expression of pull and private interests, rather than of any legitimate relations to the proper bases for rate fixing. President Stickney, of the Chicago Great Western, was quoted as expressing belief in the possibilities of a scientific system of rate making, in which rates should be computed on a mathematical basis.

No sane man holds the opinion that railway rates should be framed on a purely distance basis; but it is held that the total disregard of distance in fixing relative rates has been in very many cases a cause of great and unjust discrimination.

Regarding the contention that government rate-fixing would not prevent secret rebates, it was said that Government inspection and supervision of railway accounts was a necessary step to prevent gross discrimination and frauds on railway security holders. Prof. Hugo Meyer's book and his argument before the Senate committee, it was asserted, contained statements that were untrue, notably an alleged quotation from a German newspaper to the effect that the high rates on milk due to the German distance tariff made milk so high in Berlin that vast numbers of cows were stabled in Berlin itself.

In the discussion on these papers, no economist appeared who was ready to take the extreme "laissez faire" position assumed by Prof. Hugo Meyer, although Prof. McPherson, of Johns Hopkins, and Prof. Barrett, of Haverford, made a qualified argument on that side. The former, however, explicitly stated that no sane man contends the claim that there should be *some* form of rate regulation. The speakers on the other side, Prof. Dixon, of Dartmouth, and Prof. Fisher, of Wesleyan, quoted prominent railway officials as agreeing to the necessity of Government control of rates, and the latter referred especially to Col. H. S. Haines' recent book (Eng. News, Nov. 16, p. 533), as showing the haphazard character of rates made on the present basis, and the fact that they are really framed largely in the interest of the influential shippers.

The paper advocating municipal ownership was read by Frederick C. Howe, Esq., of Cleveland. Prof. Howe is also the author of a notable recent work, "The City: the Hope of Democracy," reviewed in our Literature Supplement for December. He argued for municipal ownership, not chiefly because of the profit or saving that might result from keeping in the public control the "unearned increment" in the great profit-yielding franchises for public service. Neither is the securing of good service on street railways, or a pure water supply, the strongest reason for adopting municipal ownership. The great and controlling reason why the cities must own these great public service utilities is to prevent the private franchise holding interests from owning and controlling the city government.

Prof. Daniels, of Princeton University, who represented the opposition to municipal ownership, took the ground that the evidence of the success of municipal ownership in foreign cities where it had been most largely adopted was not yet clear enough to justify one in commending it. He thought that economists should keep an open mind toward the municipal ownership movement, but that at present the only verdict possible was the Scotch verdict, "not proven."

Prof. Rowe, of the University of Pennsylvania; Dr. Milo R. Maltbie, of New York City, and Dr. Albert Shaw and Prof. R. T. Ely, of the University of Wisconsin, were some of the speakers who took strong ground in favor of municipal ownership. The last named speaker, in answering the plea that regulation of city franchise-holding corporations was preferable to municipal ownership, said that it was very difficult to secure effective regulation of a franchise corporation under local ownership and control. It takes a very uncommon grade of civic conscience to enable a man to publicly oppose his neighbor and friend, whose interests may be bound up in the local lighting or water company.

Prof. Fairlie, of the University of Michigan, believed it to be desirable that cities should be enabled to engage in various enterprises on the same basis as private companies, that is, to build water-works, street railways, etc., by issuing bonds based on the works themselves and not a potential burden on the real estate owners of the city. This seemed to him a safe and desirable plan for extending largely the field of municipal ownership, whereas existing debt limitations hinder many cities from advancing much further in this direction. If a city built a water-works plant on such a basis and defaulted in payment of the bonds, the bond-holders would simply take over the works, as in the case of a private company, but would have no claim upon real estate owners.

A BASCULE BRIDGE in the port of Copenhagen, Denmark, replacing the Knippel bridge, is to be built on the designs of Mr. J. B. Strauss, of Chicago, under the Strauss style of trunnion bascule construction. The successful design was selected in a competition. The completed bridge is to cost about $200,000.

TOWING THE FLOATING DRY-DOCK "DEWEY" TO THE PHILIPPINES.

The big floating dry-dock "Dewey," concerning which two articles describing the acceptance tests appeared in our issue of Dec. 7, started on its long journey of 14,000 miles from Baltimore to Olongapo, Philippines, on the afternoon of Dec. 28. This is the longest tow ever undertaken in maritime history, and is rendered doubly dangerous owing to the unwieldiness and necessarily slow speed of the huge floating structure. The general route, as laid down by the Navy Department, will be across the Atlantic, through the Mediterranean, Suez Canal, Red Sea and Indian Ocean to Singapore; thence to the Philippines across the Sea of China. Commander Hosley, U. S. N., who will have charge of the expedition, will use his own judgment in choosing special routes and solving the various problems as they arise.

The towing facilities include the powerful naval tug "Potomac" and the two colliers "Caesar" and "Brutus"; also the supply ship "Glacier," which will take a hand in the towing during good weather. The tow, when stretched out, will be about 1¼ miles long. While in fair weather the dock will draw only about 7 ft., it can be submerged to about 12 to 18 ft., to give stability in case of stormy weather. When very severe storms and high head winds are met it is calculated to throw off the tow lines and submerge the dock to a depth of 30 or 40 ft. below the surface of the sea, leaving the upper works exposed, which would, in case of need, make a safe lee for the towing vessels to lie in until the severity of the weather abated.

In the towing scheme, as described by Commander Hosley in the Baltimore "News," arrangements have been made to tow the dock by one of its end sections. Four bitt-heads are securely fastened to the top and outboard side of the section. Four more bitts are installed immediately behind these, on the main section. To these eight bitts will be securely fastened a bridle of 2½-in. chain, its apex extending about 25 fathoms out from the dock. A double part of a 15-in. water-laid hemp hawser, 100 ft. in length, will be shackled to this, the inboard end of which will be fastened to a towing machine on board a collier. The object of the towing machine is to "give and take" the strain brought upon the tow-lines in a heavy sea. The bow of the collier will be equipped with a similar chain bridle, and the same arrangement of tow-lines will be followed to the leading collier, each being fitted with a towing machine.

The crews of the convoy will be the same as when in regular service, while that of the dock will include 35 men, 22 of whom are regular sailors. The rest of the crew is made up of engineers, electricians and other mechanical experts.

ENGINEERING MATERIAL PRICES.

TRACK FASTENINGS—
Pittsburg f. o. b. cars—Angle bars, 1.75 cts.; spikes, 2 to 2.05 cts.; bolts, square nuts, 2.15 cts.; bolts, hexagonal nuts, 2.40 cts.

RAILS, STEEL—
New York—at mill—New standard sections $28; standard, second quality, $27; light sections, 12 to 25 lbs., $24 to $30; old iron, f. o. b. New York, $22.50 to $23; old steel, long lengths, $16.50 to $17.50; old steel, short pieces, $16.50 to $17.
Pittsburg—Standard sections, at mill, $28; standard, second quality, $27; light rails, 12 to 25 lbs., $24 to $30.

STRUCTURAL MATERIALS—
New York—at tidewater—Beams and channels, up to 15-in., 1.70 cts.; over 15-in., 1.80 cts.; angles, 3 × 2 and up to 6 × 6, 1.70 cts.; zees, 3-in. and larger, 1.70 cts.; tees, 3-in. and larger, 1.75 cts.; steel bars, half extras, 1.61½ to 1.74½ cts.

PLATES AND SHEETS—
New York—at tidewater—Sheared plates, tank, 1.74½ to 1.84½ cts.; flange, 1.84½ to 1.94½ cts.; marine, 1.94½ to 2.04½ cts.; still bottoms, 2.04½ cts.; fire box, 2.24½ to 3.05 cts.
Pittsburg—Tank, ¼-in. thick and heavier, 1.60 cts.; black sheets, 27 gage, 2.20 cts.; black sheets, 28 gage, 2.30 cts.

IRON—
Pig Iron:
New York—tidewater—Northern; No. 1 X Foundry, $18.75 to $19.50; No. 2 X Foundry, Northern, $18.25 to $18.75; No. 2 Plain, Northern, $17.25 to $17.75; Gray Forge, Northern, $16.50 to $17; Basic, Northern, $18 to $18.25; No. 1 Foundry, Virginia, $18.60 to $19.10; No. 2 Foundry, Virginia, $18.10 to $18.60; Basic, Virginia, $19.10 to $19.60; No. 1 Foundry,

Southern, $18.75; No. 2 Foundry, Southern, $18.25; No. 3 Foundry, Southern, $17.50 to $17.75; No. 4 Foundry, Southern, $17 to $17.25; No. 1 Soft, Southern, $18.50 to $18.75; No. 2 Soft, Southern, $18.25; Gray Forge, Southern, $16.25 to $16.75; Mottled, Southern, $15.75 to $16.25; Basic, Southern, $18.75.

Pittsburg—f. o. b. cars—No. 2 Foundry, $18.35 to $18.85; Gray Forge, $17.35; Bessemer Iron, $18.35; Ferro Manganese, $85 to $130; Muck Bars, $19 to $31; Iron Bars, $1.70.

Chicago—Lake Superior Charcoal, $20 to $20.50; Northern Coke Foundry, No. 1, $19.75 to $20; Northern Coke Foundry, No. 2, $19.25 to $19.50; Northern Coke Foundry, No. 3, $18.75 to $19; Northern Scotch, No. 1, $20 to $20.50; Ohio Strong Softeners, No. 1, $20.05 to $20.30; Ohio Strong Softeners, No. 2, $19.55 to $19.80; Southern Coke, No. 1, $18.65 to $19.15; Southern Coke, No. 2, $18.15 to $18.65; Southern Coke, No. 3, $17.65 to $18.15; Southern Coke, No. 4, $17.15 to $17.65; Southern Coke, No. 1 Soft, $18.65 to $19.15; Southern Coke, No. 2 Soft, $18.15 to $18.65; Southern Gray Forge and Mottled, $16.65 to $17.15; Malleable Bessemer, $19.50 to $20, Standard Bessemer, $19.30 to $19.55; Jackson Co. and Kentucky Silvery, 6%, $21.30; Jackson Co. and Kentucky Silvery, 8%, $22.30; Jackson Co. and Kentucky Silvery, 10%, $24.30.

Cast-Iron Pipe:

New York—Carload lots, net tons, 6-in., at tidewater, $29.75.

Chicago—4-in. water pipe, $29.50; 6-in. and larger, $28.50, with $1 extra for gas pipe.

MISCELLANEOUS MATERIALS—

Asphaltum:

Ventura and other California asphalts, $19 to $21 per ton at New York; Trinidad refined, $25 to $30 per ton; Venezuela asphalt, $25 to $30 per ton; Bermuda asphalt, $25 to $30.

Cement:

Rosendale or Natural, in wood, 85 cts. per bbl.; Portland domestic, in sacks, $1.15 to $1.20; in wood, $1.50 to $1.60; German Portland, $1.90 to $2.10.

Copper:

Lake, 18½ to 19 cts.; electrolytic, 18½ to 19 cts.; casting, 18⅝ to 18⅞ cts.

Lead:

New York, spot, 5.85 to 5.95 cts.

Spelter:

New York, spot, 5.95 to 6.05 cts.

Tin:

New York, spot, 35.25 to 35 cts.

Tar:

New York, $5.50 per bbl.

Pitch:

New York, $3 per bbl.

LUMBER—

New York, wholesale prices:

Piling—Spruce, ordinary cargoes, 6 to 7 cts.; oak, 14-in. butt, 40 to 50 ft., 19 cts.; 50 to 55 ft., 22 cts.; 55 to 60 ft., 23 cts.; 60 ft. and up, 25 cts.; pine, 60 to 65 ft., $8.50; 65 to 70 ft., $9.50; 70 to 75 ft., $10.50; 80 ft. and up, $16.

Railroad ties—Yellow pine, 6 × 9 ins. × 8 ft., 65 to 66 cts.; 6 × 8 ins. × 8 ft., 59 to 61 cts.; 7 × 9 ins. × 8 ft., 72 to 73 cts.; 7 × 8 ins. × 8½ ft., 68 to 69 cts.; 7 × 9 ins. × 8½ ft., 73 to 74 cts.

A FIREPROOF FLOOR FAILED DURING CONSTRUCTION in New York City on Dec. 30, 1905, fortunately without causing death or serious injury. The failure occurred in a six-story building of reinforced concrete being erected by the People's Tabernacle as a church auxiliary house. It was designed by the pastor of the church and was being erected by him by day labor. The building is about 26 × 80 ft. in plan, but in the larger part of its length is only about 18 ft. wide. The walls were built of concrete in the same thicknesses prescribed by the New York Building Code for brick walls; a reinforcing bar over each window or door opening, forming the lintel, and occasional longitudinal rods to prevent shrinkage cracks, were the only wall reinforcement. The floors were designed by the Trussed Concrete Steel Co. and were of combination hollow tile and reinforced concrete construction, as previously used by that company. The concrete part was essentially a ribbed floor with 2-in. plate and 4-in. ribs 6 ins. deep spaced 16 ins. on centers, the 12 × 6 in. space between the ribs being filled by a row of hollow tile laid with webs in the direction of the concrete ribs. In the narrow part of the building the ribs span from side wall to side wall, but in the forward, wider, part the ribs run from front to rear, in two bays of 10 and 12 ft. separated by and carried on a transverse girder of reinforced concrete. The building had been carried up to the fifth floor, and the front part of this floor was being laid at the time of the failure. The fourth floor just below this new work had been in place about two weeks, and still had some shores in place beneath it. The removal of one of these shores showed that the floor was too weak to carry the load of the fifth floor, and the two forward panels in question fell. The third floor held up under the shock of the falling material of the fourth and fifth floors. The failed floor area thus consists of an area about 20 × 24 ft. in each of two floors. It is necessary to state that in one corner of this area was a material hoist, served by a steam hoisting engine on the street in front of the building. The head sheave frame of the hoist rested in part on the centering of the fourth and fifth floor girders, and the concrete was probably injured, while green, by the operation of the hoist. The materials of the concrete were good, but lack of thoroughness and first-class workmanship in the concrete work is evident at several points in the structure, and it is possible that this had something to do with the failure.

FIRE DESTROYED THE NEW FERRY TERMINALS of the Central Railroad of New Jersey and the Delaware, Lackawanna & Western Ry. at West 23d St., New York City, on the morning of Dec. 20. These terminals were completed and put into service only a few months ago. With the adjoining ferry terminals of the Erie Ry. and the Pennsylvania Railroad they formed the uptown passenger entrance to New York of the principal railways arriving on the Jersey shore of the Hudson River. The Erie and Pennsylvania terminals at this point have been in existence for a number of years, with two ferry slips each. Recently, when the city undertook the extensive Chelsea dock improvements, intended to provide berths for trans-Atlantic steamers of the largest type, the plan was developed of making the 23d St. wharf a general railway terminal by providing space also for the Lackawanna and the Jersey Central, and grouping the four terminals around a large open plaza. This plan was carried out and its execution was substantially completed a few months ago when the Lackawanna terminal (two ferry slips) and the Jersey Central terminal (one slip) were put into public service. The only item still left to be done to complete the group of ferries was the reconstruction of the Erie terminal house, an old wooden structure standing some fifty feet inshore from the new pier-shed line.

The fire, which started under the Lackawanna terminal house, destroyed the two new terminals, but did not touch the old wooden Erie terminal immediately adjoining to the north, or the Pennsylvania terminal at the north end of the group.

The structures destroyed were steel-frame wood-and-metal sheathed pier-sheds, built on timber pile piers. The shore and river bottom in the West 23d St. region is very soft ground to great depth; rock is found at 175 to 180 ft. below mean tide. Pier and bulkhead construction in this bottom is accomplished by deep piling, with either spliced or lagged piles, and is subject to much settlement (up to 4 ft. total settlement has been observed at some points of the bulkhead wall in this region). Structures of maximum lightness and flexibility are dictated by these conditions. The two terminals involved in the present fire were designed accordingly. They were one-story sheds of flat-pitch steel roof-trusses on steel columns, roofed with slag on plank, and sheathed inside and out with wood boarding covered outside with copper or galvanized iron. The walls had steel studding and girts, with full-depth wooden railing strips, but no insulating filling was used in the hollow interior. The two buildings covered an irregular ground space of about 250 × 150 ft. The Lackawanna station was surmounted by a tall clock tower of construction like that of the building, and sheathed with copper.

The fire appears to have originated in waste building material and rubbish under the floor of the Lackawanna building. It spread very rapidly; this fact, combined with the failure of a fire alarm box, which delayed the arrival of fire apparatus, and low water pressure, which further delayed the work of the firemen, gave the fire good spread through the Lackawanna building and made it impossible to protect the Jersey Central building, which was continuous with it.

The woodwork of the two buildings was rather completely destroyed, and it furnished enough heat to bend and twist nearly all of the steel truss work and bracing. The clock tower of the Lackawanna building fell over during the fire. Both stations will require complete rebuilding, above the pier deck, excluding the pile-racks of the ferry slips, which were not destroyed.

A LOCOMOTIVE BOILER EXPLODED on the Erie Ry., near Judson, Ind., on Dec. 29. The locomotive was hauling a 35-car fast freight, east-bound. Four men were killed, and the entire train was destroyed by the explosion or by the fire which followed.

RAILWAY CONSTRUCTION DURING 1905 is reported by the "Railroad Gazette" and the "Railway Age," respectively, to have been 4,388 miles and 4,979 miles. The accompanying table shows by geographical divisions the locations of the new railway:

	Miles.
New Eng'and states	78.75
Middle Atlantic states	252.33
South Atlantic States	634.46
Gulf and Mississippi Valley states	661.99
Southwestern states	1,106.26
Central northern states	629.80
Northwestern states	991.88
Pacific states	622.82

THE CHICAGO DRAINAGE CANAL work is reviewed in the annual report presented by Mr. Z. R. Carter, President of the Sanitary District, at the last meeting of the old Board of Trustees on Dec. 4. On the South Branch of the Chicago River there has been delay in obtaining the necessary land for the improvements; 17,771 ft. of frontage and 708,293 acres have been acquired, leaving 5,264 ft. and 229,845 acres yet to be acquired. The cost of this part of the work has been $1,965,877 for right-of-way, $2,033,538 for dredging and docking, $2,488,049 for bridges. The improvement of the North Branch has been completed for about half the distance. At the water-power development plant at Lockport the work is behind-hand, owing to flood waters from the Des Plaines River, but it is expected the plant will be ready for operation by January, 1907. The engineering department has made surveys of the entire Des Plaines and Illinois River valleys and procured information to protect the interests of the District in attempts to collect damages for alleged overflow of bottom lands. Profiles of the two rivers have been prepared for practically all stages of water, from Joliet to St. Louis. Damage suits have been brought in almost every county bordering on these rivers for a distance of 300 miles. Two engineering parties have been engaged in the work for a year. The dams at Kampsville and La Grange are being lowered to avert as much overflowing as possible. During the year several engineering questions were successfully solved. Among them were the method of bringing water from the lake to the main channel; the annexation of the Calumet and Evanston territories, and establishing the District's ownership of the water power and the right to develop it.

STRUCTURAL STEEL SHAPES in Germany under the list of standard dimensions there in use have not proved to meet the combined requirements of simplicity and efficiency as fully as desired, and for some time past an active movement has been on foot to modify the dimensions given by the "Normal Profil Buch." The committee which has the preparation of this book in charge has decided that no change is warranted in the new edition now being undertaken. This means that the standards now in force will continue for a period of at least three years, until another edition is undertaken.

A LOCOMOTIVE WITH POPPET VALVES has been built by the Hannover Machine Works of Hannover, Germany, for furnace yard work. It is a small narrow-gage locomotive, gage about 31 ins., 36-in. drivers, and weight about 18 tons. The valves are seated on top of the cylinders in a longitudinal row. Separate inlet and exhaust valves are employed, so that each cylinder has four valves. They are actuated by cam guides on a single valve stem which is actuated by the regular rocker arm. The locomotive had a Stephenson link motion when originally built, and required for the change only the substitution of new cylinders and new valve rods. A superheater was fitted at the same time. Since the reconstruction the engine has been in regular service, averaging 90 miles per day. It is operated at speeds not exceeding 15 miles per hour, but has been run on the testing stand at more than double this speed (300 r. p. m.), the valves seating easily and without hammering.

THE USE OF ROCK ASPHALT as a filler and top dressing for macadam was noted on p. 420 of our issue of Oct. 19, 1905. In response to a request from this journal, Mr. J. A. Omberg, Jr., City Engineer, has sent us the following particulars regarding the use of the material in his city, which was the first to lay it for the purpose named:

Answering your inquiry concerning use of rock asphalt as a filler for macadam pavement, would say that I have used this material with some success. My aim was to, if possible, get a better pavement than gravel or macadam for streets where the price of asphalt or other first-class pavements prohibited their use. The pavement referred to is simply a macadam pavement, of coarse stone, the top voids of which are filled with bituminous sand. The cost of this pavement is about 80 cts. per sq. yd. (exclusive of grading), which is about 20 to 30 cts. more than the cost of macadam here. There is nothing remarkable or unexpected in the resulting pavement. It is, however, infinitely better than macadam, being almost water tight, nearly noiseless, and never "picks up." It can be cleaned like asphalt, with sweepers or hose. It does not appear to wear near so much as macadam which is natural, since the sand in the rock asphalt greatly helps in carrying the traffic. When it is first laid its appearance is poor, due to the fact that it is very difficult to roll it sufficiently. Two weeks of comparatively heavy traffic, however, gives it a good appearance and thoroughly compacts it.

A LARGE WATER-POWER ELECTRIC GENERATING PLANT in the northwestern part of the Empire of India is to be built shortly. The scheme utilizes the Jhelum River, a confluent of the Chenab, one of the branches of the Indus River. The plant is to be built about 50 miles below Srinager (or Kashmir), where a 6-mile conduit can give a head of about 400 ft. A present installation of 20,000 HP. is contemplated. An interesting feature of the headworks is that the larger part of the conduit (25,500 ft. out of 34,000 ft.) will be a rectangular wooden flume or else a wood stave pipe, such as have been used so largely in the Pacific Coast region of the United States. A masonry forebay at the end of the conduit will supply twelve main riveted steel penstocks, 30 to 36 ins. in diameter, about 800 ft. long, each provided with a standpipe and a vacuum valve. The hydraulic generators are to be Doble tangential water wheels, delivering 1,765 B. HP. each, and running at 500 r. p. m. Each of the twelve wheels is mounted on the shaft of a 1,000-KW. alternator, the wheel being overhung. The speed regulation will be accomplished by

automatic oil-pressure governors operating jet deflectors. The power to be produced at this plant will be used for industrial, railway and lighting service. It is probable that the Jhelum Valley Ry., 180 miles long, will be equipped for electric operation, and this station will supply it with current. Dredging and reclamation work, operating a silk mill in Srinager, and lighting, etc., in the towns of Srinager, Abbottabad, Murree, and Rawalpindi, will also be served from this plant. The construction of the entire work is rendered difficult by the transportation conditions. Some 200 miles of road transportation by bullock cart limit the weight of maximum piece to 4 tons. The high cost of Portland cement, $7.50 per bbl., renders concrete out of the question, so that masonry built of local stone will be used throughout. The hydraulic machinery and supplies will be furnished by the Abner Doble Co., of San Francisco, Cal. The main work in the initiation of the enterprise has been done by Major A. J. de Lotbiniere (Royal Engineers), who will also supervise the construction. Mr. A. C. Jewett, of the General Electric Co., who was connected with the Cauvery Power Plant in Mysore, for the General Electric Co., will serve as installing engineer for the government.

THE SEWAGE PUMPING PLANT on the lake front at 39th St., Chicago, was started Dec. 29. The intercepting sewer system of the South Side district terminates at this plant, and the sewage is pumped into the 39th St. tunnel, discharging into the south branch of the Chicago River. Water from the lake will also be pumped to give the necessary amount of flow in the river. The plant has a capacity of 16,000,000 gallons per day.

THE STEEL PASSENGER CAR seems to be a natural development from the steel freight car, whose practicability and efficiency has been fully demonstrated during the last few years. The Pennsylvania R. R. Co. has begun the construction of a number of steel passenger cars at its Altoona shops, but is being greatly delayed through difficulty in securing steel from the mills. The construction of various subways and tunnels has created a demand for fireproof cars, and the use of the steel car in the New York Subway has demonstrated the entire practicability of this material. With a realization of the coming demand for steel cars the American Car & Foundry Co. has already under way new shops at Berwick, Pa., with a capacity of 50 to 100 steel passenger cars per month.

A STEEL TOWER TRANSMISSION LINE is to be constructed between Ballston and Utica, N. Y. The Hudson River Electric Power Co., of Albany, is introducing an innovation in the way of substituting steel towers for the old time wooden poles. The length of the transmission line will be about 100 miles with a voltage of 60,000. The towers are to be 50 ft. high and will be made up of structural iron or steel. The foundations will be of concrete with bolts set in for fastening down the base of the towers. The distance between towers will be about 550 ft. and the cross-arms will be so arranged as to carry two separate three-phase circuits. The solidity of this construction should very materially decrease the cost of maintenance and the danger of interrupted service during storms. The details of the design are still in an experimental stage, but as soon as the first tower, which is now being constructed at Watervliet for testing purposes, receives the approval of the engineers in charge, the construction of the line will go forward at once.

PERSONALS.

Mr. J. E. Zalles has been appointed Chief Engineer in charge of the surveys for the projected Bolivian National Ry., succeeding Mr. W. L. Sisson.

Mr. Chas. B. Fuller has resigned the position of Superintendent of Track Elevation of the Chicago & Western Indiana Ry., located at Chicago.

Mr. W. M. Hobbs has resigned as Assistant to the Second Vice-President of the Chicago, Rock Island & Pacific Ry. Co., and the position has been abolished.

Mr. A. B. Mader, formerly U. S. Deputy Mineral Surveyor at Prescott, Ariz., has become Assistant Engineer for the Los Angeles Ry. Co., located at Pasadena, Cal.

Mr. W. G. Turner, Hydrographic Engineer in the U. S. Geological Survey, has been detailed to assist State Engineer Wade in making some important topographical surveys in Montana.

Mr. M. A. Zook, M. Am. Soc. C. E., of the Staff of J. G. White & Co., New York City, is in charge of a Corps of Engineers locating the line of the Havana Central Ry., between Havana and Cienfuegus.

Mr. A. Eugene Michel, formerly connected with the Department of Publicity of the International Steam Pump Co., is now with the Geo. H. Gibson Co., Advertising Engineers, Park Row Bldg., New York City.

Mr. John Mowat, formerly Chief Government Inspector on the Anacostia Bridge at Washington, Ill., has resigned to become Superintendent of Construction for the Pennsylvania Steel Co., the contractor for this bridge.

Mr. J. W. Barrie has been appointed Engineer of Maintenance of Way of the Pennsylvania Lines at Chicago. He is succeeded at Toledo, O., by Mr. R. C. Harris, of Marietta, O. Mr. W. G. Scott succeeds the latter.

Mr. Edward Duryee, who has been superintending the erection of the large cement mill at the Roosevelt Dam in Arizona for the U. S. Government, has received a permanent appointment in the United States Reclamation Service.

Dr. Octave Chanute, Past-President of the American Society of Civil Engineers, Consulting Engineer of Chicago, recently delivered an address on the "Preservation of Timber," before the Civil Engineering students of the University of Illinois.

Mr. James W. Stevenson, the new Commissioner of Bridges, of New York City, is a native of Western Pennsylvania. He was engaged in the newspaper work until he became secretary to Borough President Grout, of Brooklyn. For the past four years he has been Deputy Controller of New York City.

Mr. William B. Ellison has been appointed Commissioner of Water Supply, Gas and Electricity of New York City, by Mayor McClellan for the ensuing four years. Mr. Ellison was born and educated in Canada, where he was admitted to the bar. He has been practicing law in New York City since 1882.

Mr. John .A Bensel, M. Am. Soc. C. E., for six years Chief Engineer, Department of Docks and Ferries, New York City, has been appointed Dock Commissioner by Mayor McClellan. Mr. Bensel was an engineer on the Croton Dam, and for a number of years afterwards was with the Pennsylvania R. R. He is a graduate of the Stevens Institute of Technology, and has been for many years in the Dock Department.

Brigadier-General Theodore A. Bingham, U. S. A., has been appointed Police Commissioner of New York City by Mayor McClellan, to succeed Mr. Wm. McAdoo. The new incumbent graduated from West Point in 1879, and was assigned to the Engineer Corps as Second Lieutenant. His first work was with the Department of Arizona. Later he became disbursing officer of the Missouri River Commission and again Recorder of the Board on construction of bridges across the Missouri, Mississippi and Illinois Rivers. In 1889 he was appointed Captain and the following year was sent abroad as military attaché at Berlin. In 1892 he was transferred to Rome, returning to the United States in 1894. He was successively assigned to improvements on the Tennessee River, Instructor at Willets Point, and placed in command of a corps of engineers. Most prominent among the various positions held by General Bingham was that of Military Aide to the President and Superintendent of Public Grounds and Buildings at Washington, D. C. This position gave him entire charge of the White House and everything belonging to it. In 1903 he was detached from service at Washington, and given charge of all the Government river and harbor works on the lower Great Lakes district. While engaged in this work he met with a serious accident, which was later the cause of his retirement. As a mark of appreciation President Roosevelt made him a Brigadier General just before his retirement.

Obituary.

Mr. Everett R. Reynolds, for several years Vice-President and General Manager of the Long Island R. R., died recently at the age of 41.

Mr. H. V. Miller, inventor of the Miller Block Signal, showing signals in the engine cab, died at Chicago, Ill., Dec. 27. He was for some years Superintendent of Telegraph on the Chicago & Alton Ry.

James MacNaughton, M. Am. Soc. C. E., M. Am. Inst. M. E., President of the MacIntyre Iron Co., died of pneumonia at his apartments, 16 Central Park West, New York City, Dec. 29. Mr. MacNaughton was by profession a civil engineer, although not recently engaged in active practice. In 1876 and 1877 he was employed by the Croton Aqueduct Bureau, in connection with reservoir surveys and later was an engineer in the construction of the West Shore R. R. He was graduated from the Sheffield Scientific School at Yale in 1871.

Owen Meriwether, a Civil Engineer well known in the South and Southwest, died recently at his home in Montgomery Co., Tenn. He was born in Kentucky in 1833 and received his education at Manson Spring Academy, Spring Creek Academy, and later at Franklin College, near Nashville, Tenn. In 1854 he entered the profession of civil engineering as an assistant in locating and constructing a railroad between Memphis, Tenn., and Grenada, Miss. He served as a Civil Engineer on many of the Southern and Southwestern railroads until 1893, when ill-health forced him to retire.

ENGINEERING SOCIETIES.

COMING MEETINGS.

MICHIGAN ENGINEERING SOCIETY.
Jan. 9, 10, 1906. Annual convention at Lansing, Mich. Secy., F. Hodgman, Climax, Mich.

NATIONAL ASSOCIATION OF CEMENT USERS.
Jan. 9 to 12, 1906. Annual convention at Milwaukee, Wis. Secy., C. C. Brown, Commercial Club Bldg., Indianapolis, Ind.

NEW ENGLAND WATER-WORKS ASSOCIATION.
Jan. 10. Annual meeting at Boston, Mass. Secy., Willard Kent, Narragansett Pier, R. I.

IOWA ENGINEERING SOCIETY.
Jan. 10-12. Annual meeting at Des Moines, Ia. Secy., B. J. Lambert, 24 North Clinton St., Iowa City, Ia.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Jan. 17 and 18. Annual meeting at the Society House, 220 West 57th St., New York City. Secretary, C. W. Hunt, address as above.

NORTHWESTERN CEMENT PRODUCTS' ASSOCIATION.
Jan. 17, 18, 19. Annual convention at Minneapolis, Minn. Secy., F. H. Chapin, 10 N. Third St., Minneapolis, Minn.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.
Jan. 17, 18, 19. Annual meeting at Rockford, Ill. Secy., E. E. R. Tratman, 1636 Monadnock Block, Chicago.

INDIANA ENGINEERING SOCIETY.
Jan. 18, 19, 20. Annual meeting at Indianapolis, Ind. Secy., C. C. Brown, Commercial Club Building, Indianapolis, Ind.

AMERICAN INSTITUTE OF MINING ENGINEERS.
Feb. 21. Annual meeting at South Bethlehem, Pa. Secy., R. W. Raymond, 99 John St., New York, N. Y.

THE NATIONAL ASSOCIATION OF CEMENT USERS.—After considerable uncertainty it has finally been decided to hold the annual convention in Milwaukee, Jan. 9 to 12, inclusive, as was the original intention. The place of meeting will be the West Side Turner's Hall, which will also be used for some of the lighter exhibits. The heavier exhibits will be located in the Freie Gemeinde Hall, which is in the same block. The headquarters will be at the Republican Hotel.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.—At a meeting of the board of directors of the American Institute of Electrical Engineers on Dec. 15, Mr. John W. Lieb, Jr., was appointed trustee to represent the institute for a term of three years upon the board of trustees of the United Engineering Society invested with the care and administration of the new United Engineering Building. Mr. Lieb at the same time was made a representative of the Institute on the building committee. He succeeds Dr. Schuyler Skaats Wheeler, who by reason of his recent election to the presidency of the Institute resigns from these other bodies. The representation of the Institute therefore after the annual meeting of the United Engineering Society in January will consist of Messrs. Charles F. Scott, Bion J. Arnold and John W. Lieb, Jr., who are past presidents of the Institute in the order named. Work on the building is in active progress, and it is expected to lay the corner stone early in the spring.

NEW ENGLAND WATER-WORKS ASSOCIATION.—The annual meeting will be held Jan. 10, 1906, at the Hotel Brunswick, Copley Square, Boston. After the usual lunch at 1 p. m., the regular order of business will open at 2 p. m. with the President's address, and will later be followed by the presentation of the following paper: "Water-Works Construction of the United States Reclamation Service," by Mr. M. O. Leighton, Hydrographer In Charge, Division of Hydro-Economics U. S. Geological Survey. The annual election of officers will also be held.

MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK.—The regular meeting was held at the Chemists' Club, 108 W. 55th St., New York City, on the evening of Dec. 27. A paper was read, entitled, "History and Development of the Plane Table," by Mr. Edward M. Law, Jr., Assistant Engineer in the offices of the Borough President of Richmond. The first part of the paper was devoted to a history of the instrument, with a description of its crude form and the surveying problems it was called upon to solve. Its development was gradually traced down to the present accurate instrument. The paper stated that the plane table was not very widely used in modern times, other instruments having supplanted it. Its chief use in Government surveys has been in mapping and occasionally in filling in topographical surveys. Recently, the Boroughs of Richmond and Queens have adopted the plane table in place of the transit, for use in their regular surveys, with very satisfactory results. It is claimed for this instrument that the percentage of error is greatly reduced, and the resultant combination of field and office work greatly reduce the cost for labor. An extended and profitable discussion followed, during which many valuable points, for and against the different methods, were brought out. It seemed to be the general opinion that in a plane table survey five men were required, one leveler, two rodmen, one man for the plane-table and another to direct the rodmen.